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GUIDEBOOK TO THE GEOLOGY OF UTAH

Number 12

Geology of the East Tintic Mountains and Ore Deposits of the Tintic Mining Districts

UTAH GEOLOGICAL SOCIETY
1957
Salt Lake City, Utah

GUIDEBOOK TO THE GEOLOGY OF UTAH

Number 12

Geology of the East Tintic Mountains and Ore Deposits of the Tintic Mining Districts

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Distributed by

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
Mines Building, University of Utah

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INTRODUCTION

The objective of this guidebook is to discuss the geology of the East Tintic Mountains and the ore deposits of the Main, East and North Tintic mining districts. These have been studied in the past sixty years by many outstanding geologists, and we have attempted by a series of papers to summarize this information and to contribute new facts and idea as well. It is hoped that the presentation of these data will permit a better understanding of factors important in localizing the districts, and the ore bodies within individual mines. Imaginative exploration based on this knowledge will find district extensions and revive some of the inactive properties.

A road log concluding the guidebook will aid those not familiar with the mining districts in becoming acquainted with the geology and disposition of the ore deposits.

Figure 1 is an index map of northwestern Utah showing the location of the East Tintic Mountains and Plate 3 shows the geographic relations of mining districts, mines and towns.

The three Tintic mining districts occupy an area of approximately 25 square miles in the central part of the East Tintic Mountains. The largest district is the Main Tintic, located principally on the western side of the mountains. The East Tintic district, second in importance and youngest of the three, is entirely on the eastern slopes. The North Tintic district, up to the present relatively unimportant, includes all of the range north of the Main and East Tintic districts.

The slowly dwindling towns reflect the decline of mining activity during the last few decades. Eureka, the largest town of the area with a population of about 900, is situated at the north end of the Main Tintic district, 60 air-line miles south of Salt Lake City. Mammoth, at the south end of the Main Tintic district, and Dividend, in the East Tintic district, both have very small populations. Other towns previously flourishing in the East Tintic Mountains but now essentially abandoned, are Silver City, Diamond and Knightsville.

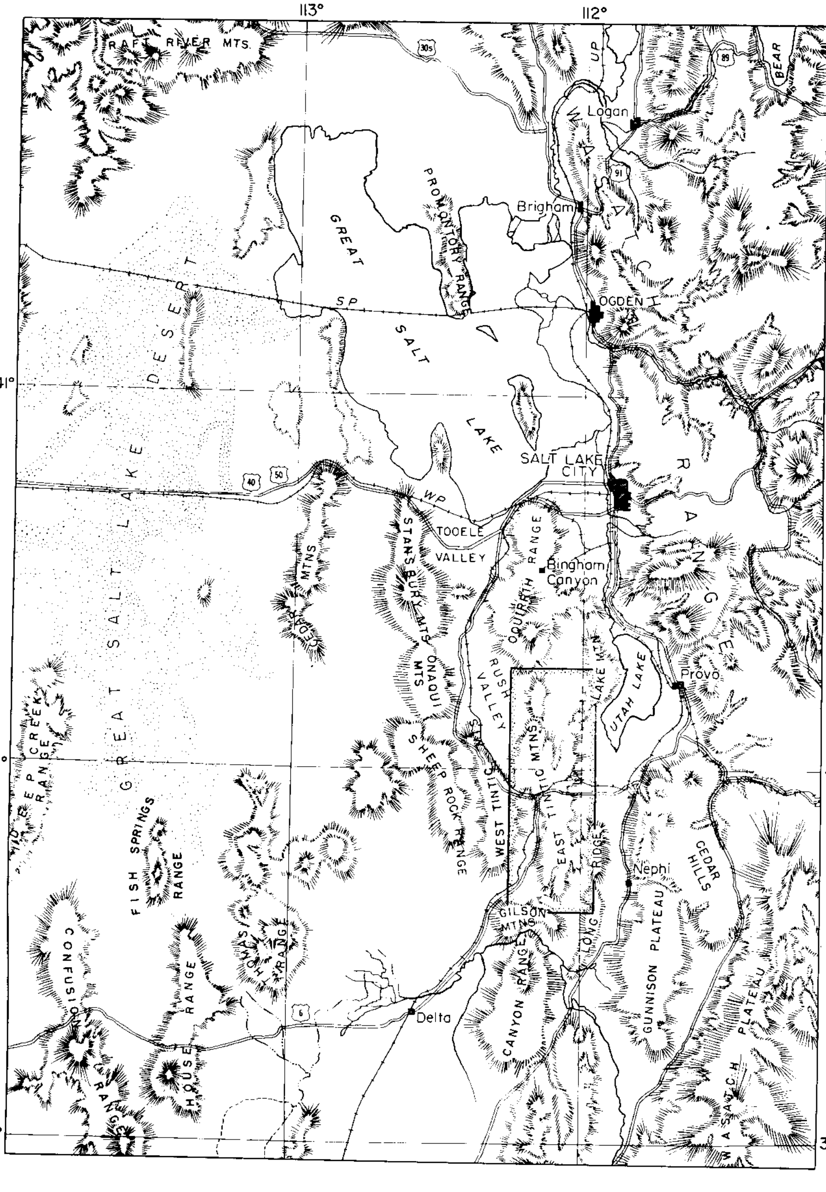

Figure 1. Index map of northwestern Utah showing location of East Tintic Mountains.

The most convenient method of travel to Eureka from Salt Lake City is by car on highways U. S. 40 and State 36 through Tooele, a distance of 90 miles. Eureka can also be reached by traveling on U. S. 6 and 50 through Provo; while this is shorter than the Tooele route, it takes longer because of traffic congestion.

From the standpoint of production, the Tintic mining districts are equal in importance to Park City and are only exceeded in the State by the West Mountain (Bingham) mining district. Recorded production is $425,000,000, chiefly from limestone replacement ore bodies. Approximately 12,000,000 tons of ore have been produced from the Main district, 3,800,000 tons from the East Tintic district and 100,000 tons from the North Tintic district. The important metal values are in silver, lead and gold with subordinate values in copper and zinc. Halloysite clay is now an important product of the Main Tintic district, and of much lesser importance is silica rock. Maganese and iron ores have been of minor importance in the past. Total profits from the mining operations are difficult to estimate but are probably close to $95,000,000. Although metal prices have risen considerably in the last two decades so have mining costs and taxes; it is doubtful, therefore, if the ores were mined today, whether net profits would be higher than those in the past.

Prior to the settlement of Utah by the Mormons in the mid 19th century, the East Tintic Mountains were part of the territory claimed by Chief Tintic of the Goshute Indian tribe. Following settlement of Utah the East Tintic Mountains were utilized for livestock grazing. In 1869 a piece of mineralized rock discovered by a cowboy led to location of the Sunbeam Claim on a fissure vein cropping out at the south end of the Main Tintic district. Discovery of other outcropping ore bodies including those of the limestone replacement type followed. The ore bodies of the East Tintic district did not crop out, and it was not until 1916 that the first major ore body was discovered. Exploration following this discovery at the Tintic Standard mine resulted in finding other important ore bodies.

At the present time mining is largely dormant with only one property, the Dragon clay mine, in operation. Nu-

merous small leases are active, however, the largest during the last few years being the Bullion Beck mine.

Two projects have been undertaken in recent years by the U. S. Geological Survey in the East Tintic Mountains. The first project was established in 1942 under the direction of T. S. Lovering and was completed in 1954; it consisted primarily of a study of the geology, hydrothermal wall-rock alteration, and ore deposits of the East Tintic district. The second project, begun in 1954 under the direction of Hal Morris, has not been completed. It consists of a study of the geology of the entire East Tintic Mountains with particular emphasis on the regional setting and possible extensions of the mineralized areas of the Main Tintic and North Tintic districts.

Several large mining companies have engaged in exploration work in recent years in the Tintic mining districts, and currently the Bear Creek Mining Company is drifting from an exploration shaft and doing surface diamond drilling.

We wish to acknowledge the help and co-operation given by the United States Geological Survey and the following mining companies:

The Anaconda Company

Bear Creek Mining Company

Chief Consolidated Mining Company

Tintic Standard Mining Company

United States Smelting, Refining and Mining Company

We also wish to acknowledge the assistance of the Utah Geological and Mineralogical Survey, especially Rosemary Van Dyke, who indexed the manuscript.

Numerous people other than those who have contributed papers have generously helped in proofreading, drafting and miscellaneous other duties. Among these are Stanley Jerome, Harry Pitts, James Anderson, William Shepard, Dona Thorpe and Ann Anderson.

THE EDITOR

GENERAL GEOLOGY OF THE EAST TINTIC MOUNTAINS, UTAH*

By

HAL T. MORRIS

U. S. Geological Survey

Menlo Park, California

INTRODUCTION

The East Tintic Mountains, which include the highly productive Main Tintic, East Tintic, and North Tintic mining districts, are a short distance northwest of the geographic center of Utah, and are essentially enclosed by meridians 112°00′ and 112°15′ west and parallels 39°40′ and 40°15′ north. (See fig. 1.) They are aligned with the Oquirrh Range to the north, and merge on the south with the foothills of the Canyon Range and the Gilson Mountains.

The East Tintic Mountains are typical of the north-trending ranges of the Basin and Range province whose origin has been attributed to block faulting. They are bordered on the west by Tintic and Rush Valleys and on the east by Dog Valley, Goshen Valley and Cedar Valley. The maximum relief from the crest of range to the floor of Goshen Valley is 3,800 feet. Boulter Peak, which attains the highest elevation in the range at 8,306 feet, is not on the main backbone divide, but west of it on a high spur between two gulches, one of which drains into Rush Valley and the other into Tintic Valley. The mountains are only moderately rugged, and most areas are easily accessible by roads and trails.

The consolidated sedimentary rocks exposed in the East Tintic Mountains are strongly folded and complexly faulted; they range in age from Late Precambrian to Permian and exceed 32,000 feet in total thickness. The semiconsolidated and unconsolidated sedimentary rocks range in age from middle Eocene to Recent, and with the exception of a middle Eocene conglomerate, are chiefly late Tertiary, Quaternary and Recent valley fill deposits in the intermontane basins.

Throughout the greater part of the southern two-thirds of the East Tintic Mountains the consolidated sedimentary

*Publication authorized by the Director, U. S. Geological Survey.

rocks are largely concealed beneath quartz latite and latite flows and pyroclastic deposits of middle Eocene age, which were erupted over a surface comparable to the present terrain of the mountains. This Eocene surface is to a large extent being exhumed through accelerated erosion of the volcanic rocks, which are commonly more hydrothermally altered and, consequently softer than the sedimentary rocks.

In the west-central part of the mountains the sedimentary rocks and extrusive igneous rocks are cut by quartz monzonite and monzonite stocks, plugs, and dikes; associated with these intrusive rocks are the extensive silver, lead, copper, gold, and zinc ore bodies for which the Main Tintic and East Tintic mining districts are so widely known.

Two projects have been undertaken by the U. S. Geological Survey in the East Tintic Mountains. The first project was established in 1942 under the direction of T. S. Lovering and was completed in June 1954; it consisted of a study of the geology, hydrothermal wall-rock alteration, and ore deposits of the East Tintic mining district, and in addition, included the mapping of the Allen's Ranch quadrange in the northeastern part of the range by P. D. Proctor and his coworkers. The second project, which was begun in July 1954 under the direction of the writer and as yet has not been completed, consists of a study of the geology of the entire East Tintic Mountains with particular emphasis on the regional setting and possible extensions of the mineralized areas of the Main Tintic and North Tintic mining districts. Personnel assigned to the second project also included A. E. Disbrow, who has studied the geology of the northwestern part of the range and H. D. Goode who studied the geology of the unconsolidated deposits of the mountains and adjoining valleys.

The following report is intended to be a generalized digest of the data gathered by both U. S. Geological Survey projects. These data will be presented in more complete publications later. All members of both projects therefore contributed to the factual data contained in this report, but the writer must accept the responsibility for any possible inaccuracies in the interpretive views expressed. Fossils listed in this report were identified by members of the Paleontology and Stratigraphy Branch of the U. S. Geologi-

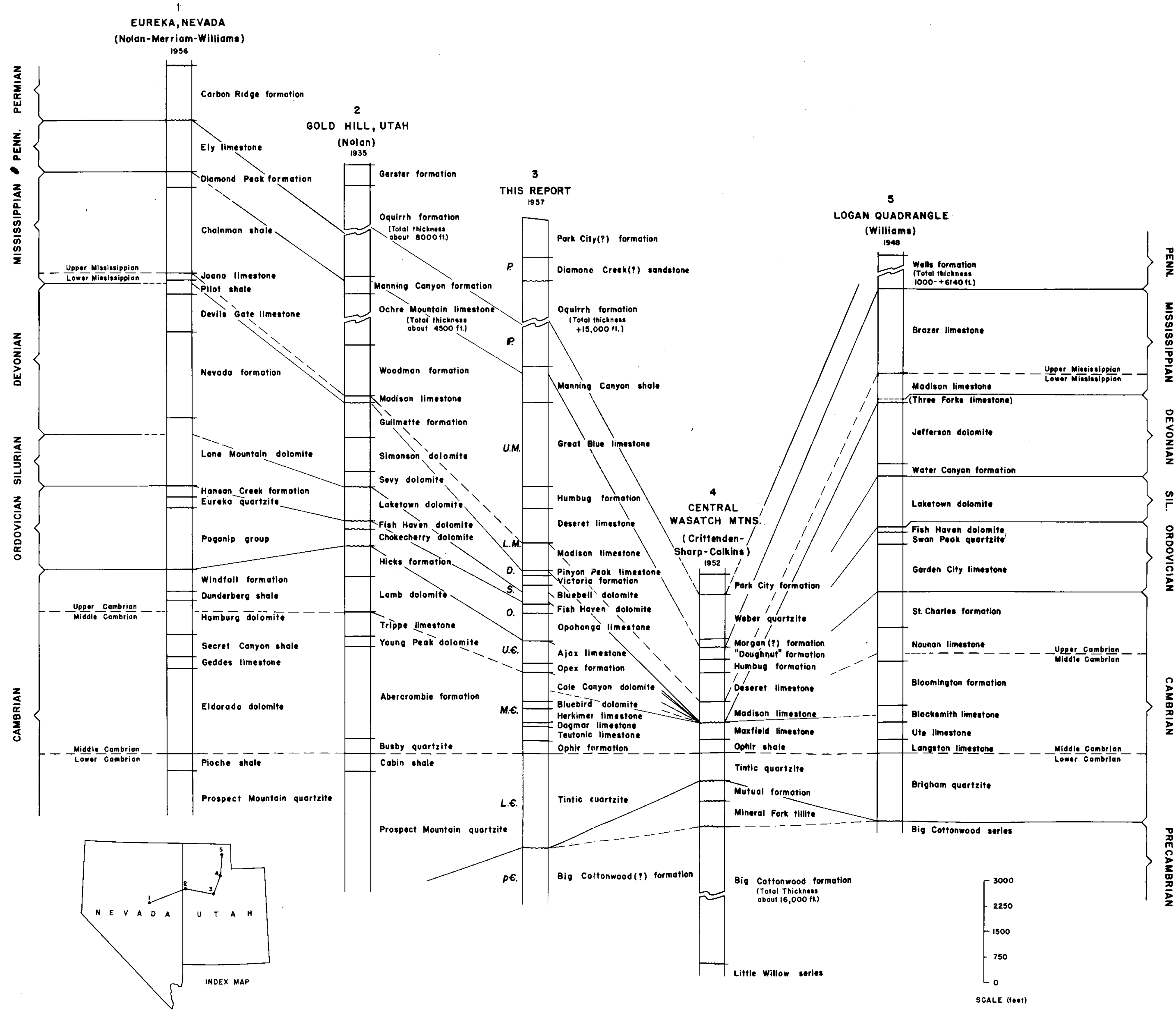

Plate 2. Correlation diagram of Paleozoic rocks, northern Utah and east-central Nevada.

cal Survey. Special acknowledgement is made of the work of Helen Duncan, Jean Berdan, Mackenzie Gordon and Allison Palmer of this organization.

The scale of the generalized geologic map, plate 1 (in pocket), is inadequate to show all of the geographic features and mines referred to in the text. However, the general location of most of these features is indicated in reference to features that are shown on the map, and all may be found on topographic maps of the area published by the U. S. Geological Survey, or on maps accompanying other sections of this Guidebook.

SEDIMENTARY ROCKS

PRECAMBRIAN SYSTEM

Big Cottonwood(?) formation

The oldest sedimentary rocks exposed in the East Tintic Mountains are provisionally correlated on the basis of color, lithologic characteristics, and stratigraphic position with the Upper Precambrian Big Cottonwood formation of the central Wasatch Range (see pl. 2). These rocks in the East Tintic Mountains consist mainly of gray-green phyllitic shale and medium-grained, gray-green, brown-weathering quartzite, but include at least one bed of brown-weathering, massive limestone. Both the shale and the quartzite beds are cut by many narrow gash-veins of milky quartz, which are a characteristic feature of the formation. Approximately 1,675 feet of beds discomformably underlie the Tintic quartzite in sec. 3, T. 10 S., R. 3 W., but the base is concealed. No angular discordance can be recognized between the Big Cottonwood(?) formation and overlying Tintic quartzite, but the occurrence of phyllitic shale below the basal conglomerate of the Tintic quartzite at one exposure and of quartzite with interbedded phyllitic shale at a nearby locality suggests the planation of low-dipping beds of the Big Cottonwood(?) before deposition of the basal conglomerate of the Tintic.

CAMBRIAN SYSTEM

Lower Cambrian series

Tintic quartzite

The Tintic quartzite was named by Smith, Tower, and Emmons (1900, p. 1) from exposures in the Tintic mining district. It is composed principally of well-bedded, medium-grained, buff-colored quartzite, but quartzite conglomerate beds are common throughout the lower half or more of the formation, and are the dominant rock within 300 feet of the base. (See fig. 2.) The lowest conglomerate beds consist of rounded pebbles of milky quartz embedded in a matrix of grit-sized sand grains stained purplish red by minute flecks of hematite. Moderately thick beds of medium-grained, gray-green sericitic shale are common within the upper 500 feet of the formation, but are locally concealed at their outcrop by surface debris. Approximately 980 feet above the base at many of its exposures the Tintic includes a sheet of amygdaloidal basalt 2 to 30 feet thick. This flow now consists of serpentine, kaolinite, sericite, calcite, and iron oxides, but retains its original porphyritic texture. The amygdules are composed largely of calcite, chlorite, and chalcedony. The top of the Tintic quartzite is placed at the top of the uppermost buff-colored quartzite below the olive-green shale of the lower member of the Ophir formation. The total thickness of the Tintic is 2,300 to 3,200 feet.

Middle Cambrian series

Ophir formation

The Ophir formation was named by B. S. Butler (Lindgren, Loughlin and Heikes, 1919, p. 25) from its type locality in the Ophir mining district in the Oquirrh Range. In the East Tintic Mountains it is 275 to more than 400 feet thick, and is subdivided into a lower shale member, a middle limestone member, and an upper shale member. The lower shale member, which conformably overlies the Tintic quartzite, is 135 to 180 feet thick, and consists of gray- to olive-green sericitic shale with a bed of medium-grained, brown-weathering, porous sandstone about 10 feet thick at the base, and an 8- to 15-foot thick bed of medium- to fine-grained, blue-gray argillaceous limestone (or hydrothermal dolomite)

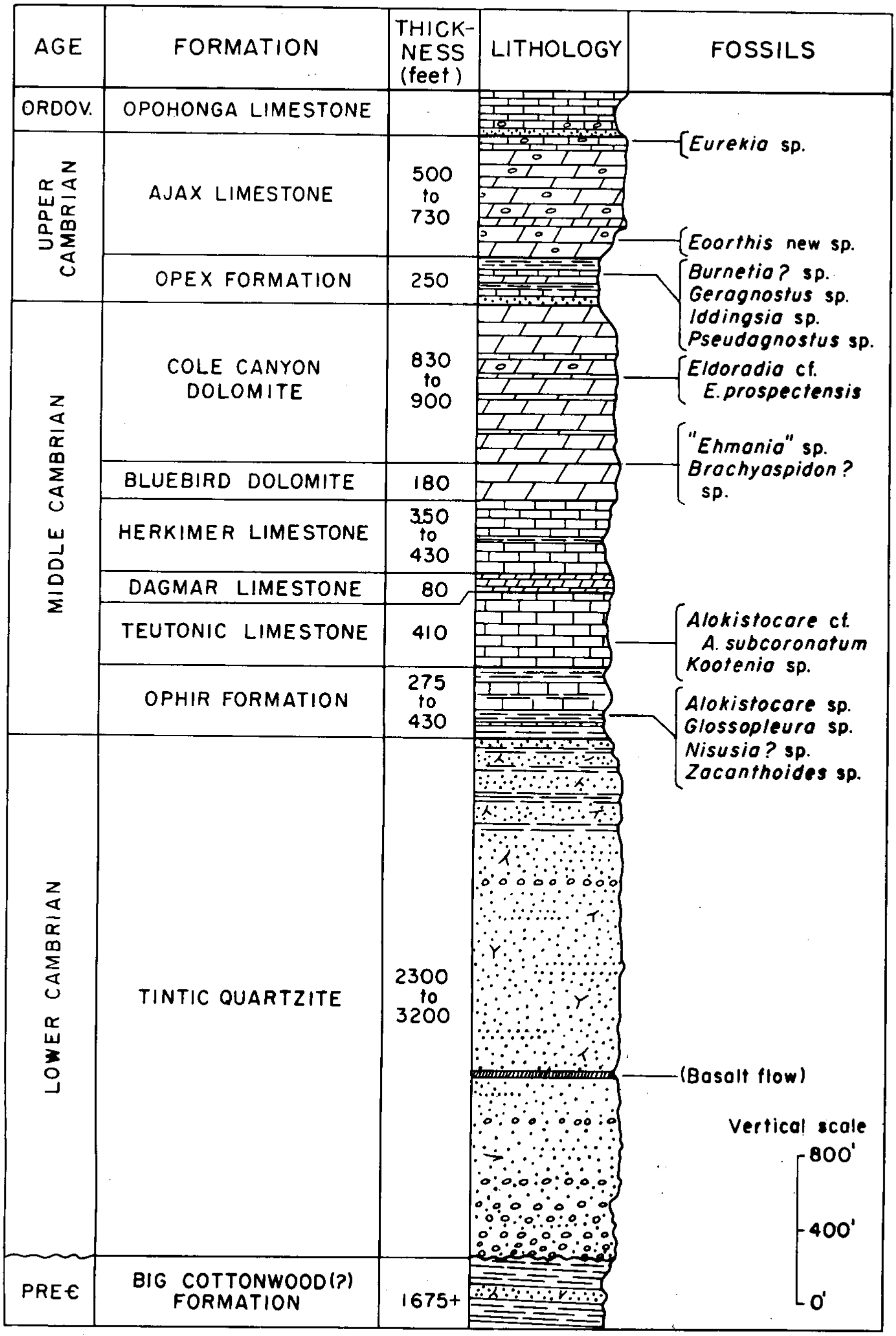

Figure 2. Columnar section of Cambrian rocks

near the center. The middle limestone member is about 75 to at least 160 feet thick and consists of 2 to 5 or more beds of medium- to fine-grained, blue-gray, mudstone-streaked limestone interlayered with olive-green shale beds 3 to about 40 feet thick. The lowest of the limestone beds commonly contains fragments of trilobites and brachiopods. The upper shale member, which is 35 to about 90 feet thick, consists of a single bed of greenish-gray to buff, fissile shale with many lenses of fine-grained limy sandstone and sandy shale.

Teutonic limestone

The Teutonic limestone was named by Loughlin (1919, p. 27)* from its type locality at Teutonic Ridge 1½ miles west of Eureka. The Teutonic conformably overlies the Ophir formation, and is 375 to 425 feet thick. The lower 80 to 100 feet of the Teutonic is medium- to fine-grained, blue-gray limestone, which is mottled and streaked with brown- and yellow-weathering mudstone and limy shale. The basal bed commonly contains globular algal structures ⅛ to ½ inch in diameter. The middle part of the formation is less argillaceous and somewhat darker blue than the lower part, and contains many oolitic and pisolitic beds. The upper part is chiefly thin-bedded, medium- to fine-grained, blue-gray argillaceous limestone similar to the lower beds.

Dagmar limestone

The Dagmar limestone, which conformably overlies the Teutonic, was named by Loughlin (1919, p. 27) from its type locality near the Dagmar mine a mile west-northwest of Eureka. It is an easily recognized unit 75 to about 100 feet thick consisting of dense, medium- to light-gray, laminated dolomitic limestone that weathers creamy-white. It is medium- to well-bedded and characteristically breaks into straight-sided blocks. The color of the rock on fresh fractures is medium- to dark-gray, the creamy-white surface being the result of accumulations of insoluble white clay. The top of the Dagmar is sharply defined by the overlying

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*The Geology and Ore Deposits of the Tintic Mining District, Utah, U. S. Geological Survey Professional Paper 107, was written jointly by Waldemar Lindgren, G. F. Loughlin and V. C. Heikes. Part I of this Professional Paper: General Geography and Geology, was prepared by Loughlin. The above reference and several successive references will be made only to Loughlin to avoid rference to Lindgren and Heikes who prepared the sections titled, "Ore Deposits" and "History and Production," respectively.

blue-gray limestone of the Herkimer, but the bottom is commonly gradational through 10 feet or more, and is placed at the base of the lowermost laminated bed.

Herkimer limestone

The Herkimer limestone was named by Loughlin (1919, p. 28) from its type locality near the Herkimer shaft 1¼ miles south-southwest of Eureka. It comfortably overlies the Dagmar limestone, and is 350 to about 430 feet thick. The Herkimer is subdivided into three members: 1) a lower member about 180 feet thick composed of medium-bedded, blue-gray limestone mottled by thin discontinuous layers and irregular splotches of yellowish-brown argillaceous material, 2) a shale member about 20 feet thick that resembles shale beds in the Ophir formation, and 3) an upper member from about 150 to about 250 feet thick composed of thin beds of limestone, limestone flat-pebble conglomerate, and calcareous oolite all separated by shale partings. At places where it has been hydrothermally dolomitized the Herkimer closely resembles the Bluebird dolomite which overlies it.

Bluebird dolomite

The Bluebird dolomite was named by Loughlin (1919, p. 28) from its type locality on Bluebird Spur a mile west of Eureka. It is 150 to 220 feet thick, and throughout the central part of the East Tintic Mountains consists of dusky blue-gray, medium-grained dolomite studded with short white dolomite rods a centimeter (0.4 inch) or so long and 1 to 2 millimeters (about 0.04 to 0.08 inch) in diameter. The white rods are straight, slightly curved or branched, and resemble minute twigs in shape. Although no organic structures are preserved, they seem to be of organic origin. Locally, in the North Tintic mining district, and in exposures at the head of Ferner Valley and near Little Dog and Dog Valleys, the Bluebird is a fine- to medium-grained, medium blue-gray, argillaceous limestone that closely resembles the lower member and parts of the upper member of the Herkimer limestone. It is not mapped as an individual formation in these areas except where it can be correlated with its dolomite counterpart, or where its position can be estimated by

measuring upward from the top of the shale member of the Herkimer limestone.

Cole Canyon dolomite

The Cole Canyon dolomite, which conformably overlies the Bluebird dolomite, was named by Loughlin (1919, p. 28-29) from its type locality along the upper west slope of Cole Canyon, which extends north from Eureka Gulch ¾ mile west of Eureka. As now mapped by the U. S. Geological Survey it is 830 to about 900 feet thick, and includes the lower dolomite member of the Opex dolomite as originally defined by Loughlin (1919, p. 30). The lower 600 feet or so of the Cole Canyon consists of alternating beds of light-gray laminated dolomite resembling the Dagmar limestone, and massive, dusky blue-gray, commonly "twiggy" dolomite resembling the Bluebird dolomite. The light-gray beds weather creamy-white; they are a foot or so to about 25 feet thick, but one rather massive, light-gray weathering bed is 60 to 90 feet thick. The dark colored beds are 10 to 30 feet thick. The zone that was originally part of the Opex dolomite but is now considered part of the Cole Canyon dolomite contains few if any interlayered white beds. It is 125 to about 300 feet thick, and consists chiefly of dusky blue-gray dolomite with some "twiggy" beds, and some beds of mottled, cross-bedded, dusky blue-gray dolomite. The base of the Cole Canyon is placed at the base of the lowest creamy-white laminated dolomite, and the top is placed at the base of the sequence of thin-bedded limestones and dolomites of the Opex.

Upper Cambrian series

Opex formation

The Opex formation was named by Loughlin (1919, p. 29-30) from exposures near the Opex mine, half a mile north-northwest of Mammoth. It concordantly overlies the Cole Canyon, but may be separated from it by a slight disconformity. The thickness ranges from about 150 to more than 350 feet and is about 250 feet near Eureka. The Opex consists of alternating thin and thick beds of shaly oolitic limestone, flat-pebble conglomerate, medium- and coarse-grained, brown-weathering sandstone and dusky blue-gray dolomite.

One or more thick beds of red and green shale occur at the top of the formation in some places, but are not everywhere present. It is an easily eroded, structurally incompetent formation, and is commonly concealed at the surface by rock debris and soil.

Ajax limestone

The Ajax limestone, which was named by Loughlin (1919, p. 31-32) from exposures near the Ajax (Gold Chain) mine ¼ mile east of Mammoth, conformably overlies the Opex formation. It was considered by Loughlin to be of Early Ordovician age, but has since yielded fossils of Late Cambrian age. The thickness ranges from less than 500 to about 730 feet. The Ajax is subdivided into three members: 1) a lower member 90 to 180 feet or more thick, 2) the Emerald dolomite member about 30 feet thick, and 3) an upper member averaging about 450 feet in thickness. The lower member is chiefly medium- to coarse-grained, medium to dark blue-gray, faintly mottled dolomite which encloses many pods and short lenses of black and brown chert. The Emerald member is a massive bed of medium-grained creamy- or grayish-white dolomite marked or mottled by irregular zones of coarse-grained gray to white dolomite. The upper member closely resembles the lower member, but is somewhat more well-bedded and contains considerably more chert, some of which is pink or white and occurs in persistent thin beds. The upper member is chiefly dolomite, but locally contains some thin-bedded argillaceous limestone at the top.

ORDOVICIAN SYSTEM

Lower Ordovician series

Opohonga limestone

The Opohonga limestone was named by Loughlin (1919, p. 32-34) from exposures near the Opohonga mine, half a mile or less southeast of Mammoth. It conformably overlies the Ajax limestone and is 400 to more than 1,000 feet thick. It is a repetitious sequence of medium- to fine-grained, thin-bedded, light blue-gray argillaceous limestone and flat-pebble conglomerate that is streaked with thin layers and veinlets of siliceous clay which weather buff, yellow and red. In

cross-section the clay seams divide and rejoin in a pattern resembling flattened hexagons. The base of the Opohonga is marked by a bed of brown-weathering limy sandstone or sandy limestone (see fig. 3). The limestone beds immediately overlying the sandstone bed enclose large nodules of white chert that are not present in the middle and upper parts of the formation.

Upper Ordovician series

Fish Haven dolomite

No Middle Ordovician rocks are present in the East Tintic Mountains, and the Opohonga limestone is disconformably overlain by the Upper Ordovician Fish Haven dolomite. This name is currently applied in the East Tintic Mountains to the lower third of the Bluebell dolomite of Loughlin (1919, p. 34-36). In reference to G. W. Crane's informal subdivisions of the Bluebell formation of Loughlin, the Fish Haven includes the "Eagle dolomite" plus the lower half or so of the "Beecher dolomite," extending to the base of the "No. 21 beds." (Unpublished notes on file at Chief Consolidated Mining Co.)

The Fish Haven consists entirely of thin- and massive-bedded, medium- to coarse-grained, dark- to light-gray dolomite. Chert nodules are sparsely distributed near the base and are abundant in the upper third of the formation. Corals and brachiopods characteristic of the widely distributed Late Ordovician fauna are moderately common in massive beds at both the top and the bottom of the formation. Significant fossils are:

- *Aulacera* cf. *A. undulata* (Billings)
- *Streptelasma trilobatum* Whiteaves
- *Palaeophyllum* sp.
- *Catenipora rubra* Sinclair and Bolton
- *Calapoecia* sp.
- *Favosites (Favosites)* sp.
- *Lepidocyclus perlamellosus* (Whitfield)
- *Lepidocyclus rectangularis* Wang

The top of the Fish Haven is placed at the top of a thick, conspicuously mottled, massive dolomite bed known locally as the "leopardskin" marker bed. The thickness of the Fish Haven ranges from 275 to approximately 350 feet; near Eureka it is about 285 feet.

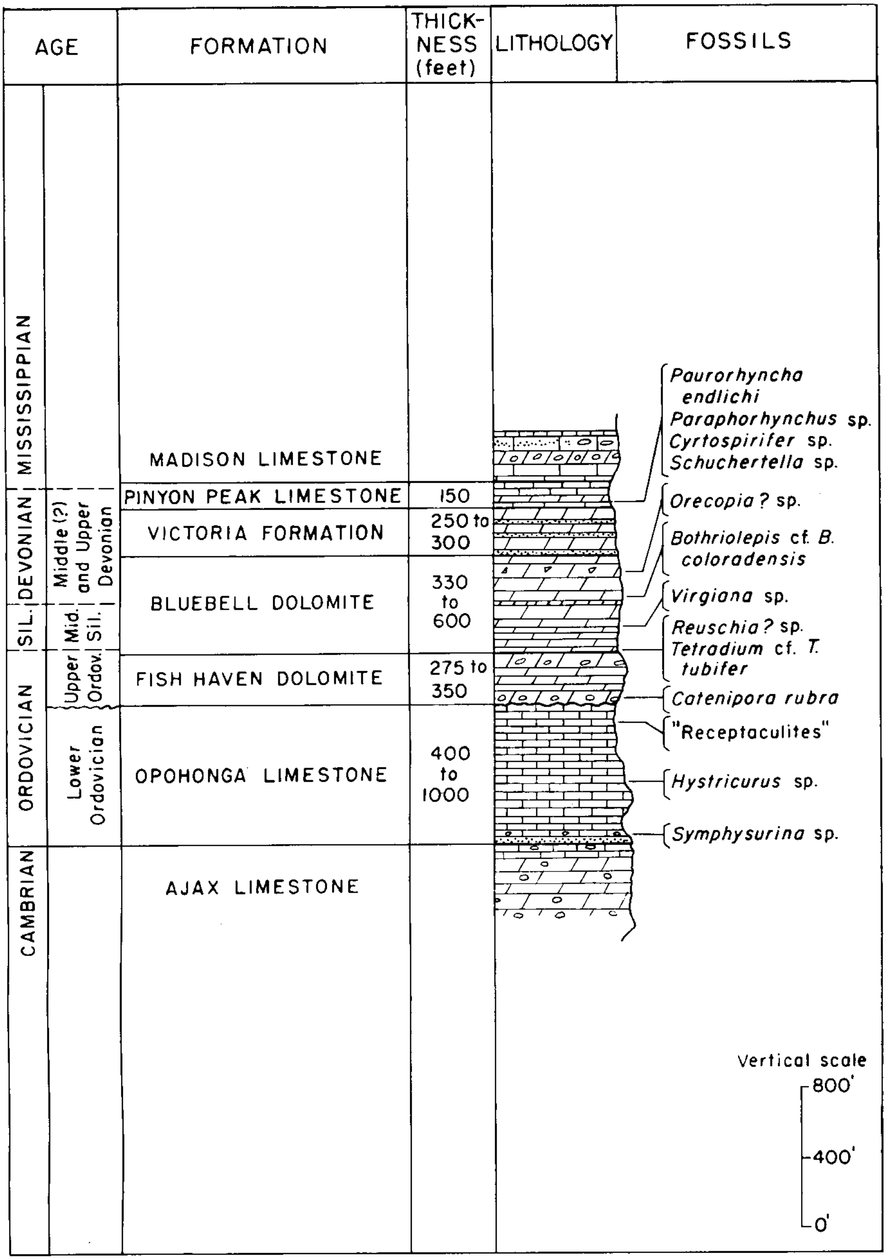

Figure 3. Columnar section of Ordovician, Silurian, and Devonian rocks

ORDOVICIAN, SILURIAN AND DEVONIAN SYSTEMS

Bluebell dolomite

The Bluebell dolomite, which conformably overlies the Fish Haven dolomite, was named by Loughlin (1919, p. 34) from exposures near the Eagle and Bluebell mine, half a mile or so south of Eureka. It includes beds that contain moderately well-preserved fossils of Late Ordovician, Silurian, and Devonian age, but the systemic boundaries within the formation cannot be recognized by lithologic differences. The thickness ranges from less than 350 to about 600 feet, but the average is about 550 feet near Eureka. Throughout the East Tintic Mountains the Bluebell may be separated into 2 members of nearly equal thickness by a bed of crinkly-laminated, medium- and light-gray dolomite about 10 feet thick known locally as the "curly bed" or "Colorado Chief" marker. The laminae are less than a millimeter (about 0.04 inch) to a centimeter (about 0.4 inch) or so in thickness and define dome- or biscuit-shaped structures a few inches or less in diameter.

The lower member of the Bluebell is chiefly light- to medium-gray weathering, thin- to medium-bedded, medium- to fine-banded dolomite that becomes darker and more massive near the "Colorado Chief" marker bed. In contrast, the upper member is principally medium- to dark-gray, medium- to thick-bedded, medium- to coarse-grained dolomite that locally contains almond-shaped pods of white dolomite 1 to 2 inches long and ½ to 1 inch thick. The basal beds of the Bluebell consist of medium- to thin-bedded, fine-grained, white-weathering dolomite, and are referred to locally as the "No. 21 beds." The base of the first sandstone or quartzite bed in the overlying Victoria formation defines the top of the Bluebell dolomite.

DEVONIAN SYSTEM

Upper Devonian series

Victoria formation

The Victoria formation was named by Loughlin (1919, p. 38-39) from its outcrop near the Victoria mine ¾ mile south-southeast of Eureka. It conformably overlies the Bluebell dolomite and is 250 to 300 feet thick. As currently de-

fined by the U. S. Geological Survey the Victoria formation includes all the Victoria quartzite as it was originally described, plus 70 to 80 feet of mottled coarse-grained dolomite, now known to be of Devonian age, that was formerly placed in the lower part of Loughlin's Gardner dolomite. The lower 200 feet or so of the Victoria formation consists of well-bedded, medium- to fine-grained, wood-ash gray dolomite interlayered with thin and thick beds of brown-weathering dolomitic sandstone. Many of the sandstone beds have irregular lower contacts that seem to mark channels, and some are intraformational breccias containing angular blocks of sandy dolomite as much as 15 inches or more in diameter. Within a few feet of the base of the Victoria is the "speckled-bed," a highly distinctive marker of medium-grained, medium-gray dolomite 1 to 3 feet thick that is crowded with small aggregates of tiny well-formed crystals of white dolomite. The upper boundary of the Victoria is placed at the top of the uppermost dolomite bed that underlies the thin-bedded shaly limestones of the Pinyon Peak limestone. This contact marks a disconformity of virtually no consequence in the East Tintic Mountains, but it corresponds to the major pre-late Late Devonian unconformity that is recognized in the Stansbury Mountains, Oquirrh, central Wasatch and eastern Uinta Ranges.

DEVONIAN AND MISSISSIPPIAN(?) SYSTEMS

Pinyon Peak limestone

The Pinyon Peak limestone was named by Loughlin (1919, p. 36) from exposures on the east side of Pinyon Peak. He did not recognize it in the Tintic district where he believed the Victoria formation to be of Mississippian age and to overlie an unconformity at the base of the Mississippian sequence. Consequently, he unknowingly included the Pinyon Peak limestone with his Gardner formation in this area, and failed to recognize the true age of the Victoria. Stratigraphic data gathered since 1947 demonstrate that the Pinyon Peak limestone occurs throughout the East Tintic Mountains immediately above the Victoria formation. Fossils collected by the U. S. Geological Survey indicate that the Devonian-Mississippian boundary is in the upper part of the Pinyon Peak; thus, the age of the Pinyon Peak is considered Late Devonian and Mississippian(?).

The Pinyon Peak consists chiefly of thin-bedded, fine-grained, medium- to light-blue limestone seamed with wispy veinlets and partings of buff- to brown-weathering clay and mudstone. In the northern part of the East Tintic Mountains the base is marked by a thin bed of light-gray quartzite or sandy shale, but this bed is not found near Eureka. The top of the formation is gradational with the overlying Mississippian Madison limestone, and is arbitrarily placed at the base of a thin bed of calcareous sandstone or sand-streaked limestone referred to as the "sand-grain" or "ant-egg" marker by the mining geologists of the Tintic district. The Pinyon Peak is about 70 to 300 feet thick.

MISSISSIPPIAN SYSTEM

Lower Mississippian series

Madison limestone

The name Madison limestone is preferred to the name Gardner dolomite for the rocks of Lower Mississippian age in the East Tintic Mountains inasmuch as the Gardner dolomite, as originally defined (Loughlin, 1919, p. 39-40), erroneously included some beds of Late Devonian age, and the name was essentially restricted in its usage to the East Tintic Mountains. In a Professional Paper currently being prepared on the stratigraphy of the East Tintic Mountains by the writer and T. S. Lovering, Madison is used as a group name. This group includes two new formations which are equivalent to the lower and upper members of the Madison limestone of this report. The names proposed for these two new formations have not as yet been officially adopted by the U. S. Geological Survey and are therefore not used in this report.

Lower member

The lower member of the Madison limestone of the East Tintic Mountains is 250 to about 350 feet thick; near Eureka the average is 280 feet. (See fig. 4.) The lower member consists of 8 individually distinctive lithologic units that are persistent throughout the East Tintic Mountains. In sequence from the base these units include: 1) the "sand-grain" marker bed 6 inches to 3 feet or more thick, 2) a thin-bedded, blue, argillaceous limestone which resembles

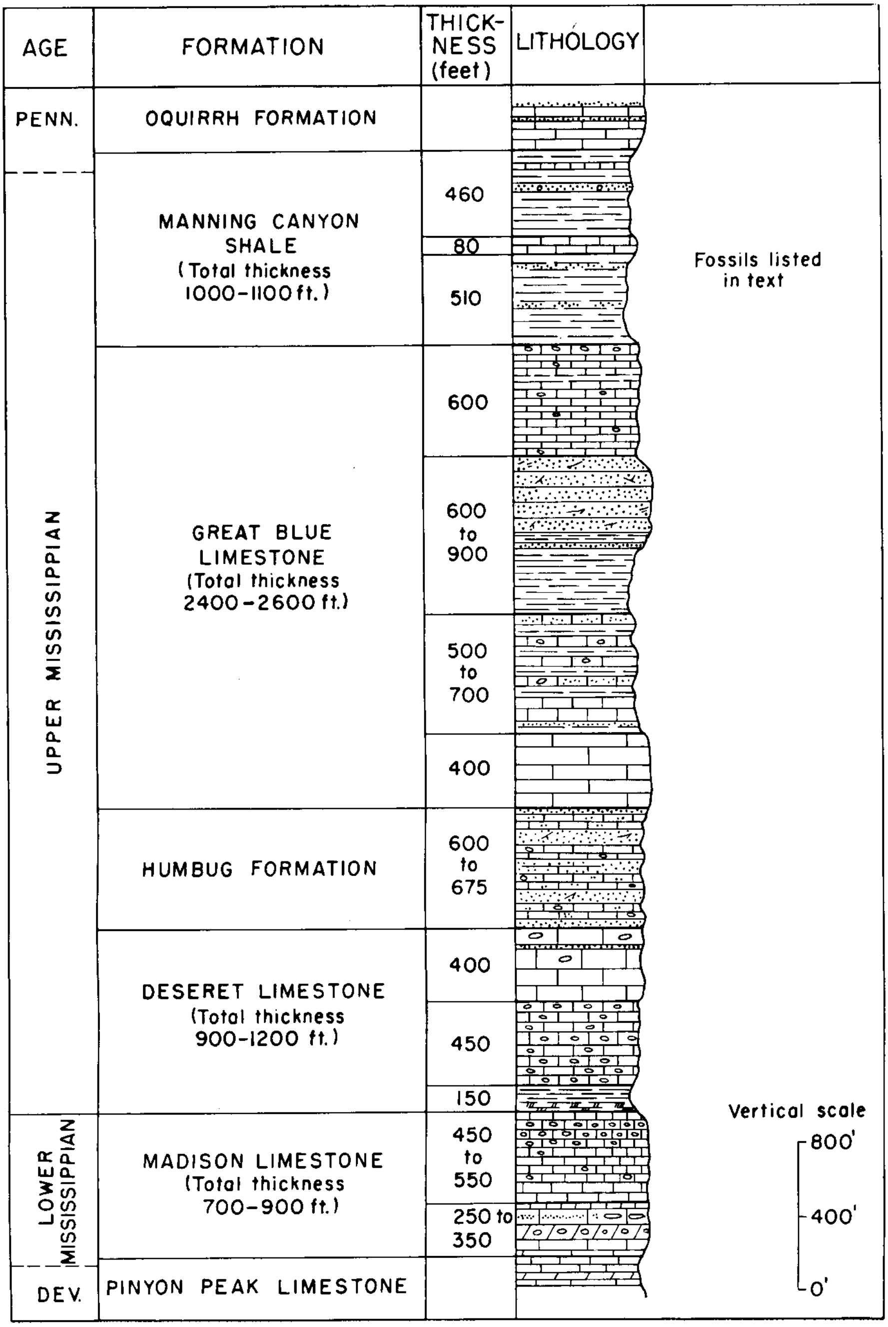

Figure 4. Columnar section of Mississippian rocks

the Pinyon Peak limestone, 3) a massive light-gray to white limestone, 4) a thin-bedded, blue-gray, fossiliferous, shaly limestone, 5) a coarse-grained, dusky blue-gray to black, cherty dolomite with conspicuous eye-shaped pods of white calcite and dolomite, 6) a medium-grained, medium- to dark-gray dolomite with one or more beds of novaculitic quartzite near the middle, 7) a dense pink limestone, and 8) a bed of crenulated, dense medium- and dark-gray laminated limestone, the "curly limestone" of local usage.

The "curly limestone" marker that defines the top of the lower member has recently been described in considerable detail by Proctor and Clark (1956, p. 313-321). It is 8 to 30 or more inches thick, and is believed to be of algal origin.

Fossils collected from the lower member include the following forms:

From "blue shaly" unit about 125 feet above base.

Caninoid corals
Clisiophyllid corals
Avonia? sp.
Schuchertella? sp. indet.
Spirifer sp.
Rhynchonelloid brachiopod, indet.

From "blue shaly limestone" and "black cherty dolomite" units between 103 and 215 feet above base.

Dipterophyllum? sp.
Caninia sp. indet.
Clisiophyllid coral, gen. and sp. indet.
Syringopora aculeata Girty
Syringopora surcularia Girty
Spirifer, 2 spp.
Syringothyris sp.

Upper member

The upper member of the Madison limestone of the East Tintic Mountains is further subdivided into 1) a lower unit of medium- to well-bedded, medium to dark blue-gray fossiliferous limestone that is fine grained near the base and grades upward into coarse-grained, locally cross-bedded, clastic limestone; and 2) an upper unit of mostly well-bedded, fine-grained fossiliferous limestone that contains abundant nodules and layers of light-gray, brown- and black-weathering cherts that in many places make up 30 percent or more

of the rock. The lower unit is approximately 375 feet thick, and the upper unit is approximately 125 feet thick.

The upper member of the Madison limestone is the lowest unit in the stratigraphic column of the East Tintic Mountains in which fossils are abundant and well preserved. The following forms have been identified:

From upper half of upper member:

Zaphrentites? sp.
Rotiphyllum? sp.
Cyathaxonia sp.
Cystelasma sp.
Vesiculophyllum sp.
Lithostrotionella sp.
Syringopora cf. S. surcularia Girty
Fenestella, several spp.
Leptaena cf. L. analoga (Phillips)
Orthotetinid brachiopods, undet.
Pustula sp.
Linoproductus sp.
Spirifer aff. S. centronatus Winchell
Spirifer sp.
Martinia? rostrata Girty
Composita sp.
Naticopsis? sp.

From lower half of upper member:

Cystelasma sp.
Homalophyllites sp.
Zaphrentites cf. Z. excavatus (Girty)
Vesiculophyllum sp.
Michelinia sp.
Auloporoid corals
Syringopora sp.
Fenestella sp.
Schuchertella sp.
Chonetes loganensis Hall and Whitfield
Productus aff. P. sedaliensis Weller
Pustula sp.
Punctospirifer solidirostris (White)
Spirifer centronatus Winchell
Composita claytonia Hall and Whitfield
Dielasma? sp.
Camarotoechia?, 2 spp.
Aviculopecten? sp.
Straparollus (Euomphalus) ophirensis Hall and Whitfield
Straparollus (Euomphalus) utahensis Hall and Whitfield
Proetus cf. P. loganensis Hall and Whitfield

Upper Mississippian series

Deseret limestone

The name Deseret limestone is currently applied by the U. S. Geological Survey to the Pine Canyon limestone of Loughlin (1919, p. 40-41) inasmuch as it has received wider acceptance as a stratigraphic name, and Loughlin locally included within the boundaries of the Pine Canyon the upper cherty member of the Gardner dolomite which is the upper unit of the upper member of the Madison limestone of this report.

The Deseret limestone consists of 3 members: 1) a basal phosphatic shale, 2) a lower limestone member, and 3) an upper limestone member.

Phosphate

The basal phosphatic shale is 10 to about 150 feet thick. It consists chiefly of sooty-black phosphatic shale interlayered with dark-gray to black cherty limestone, but includes near the base, especially near Eureka, one or more beds of pelletal phosphorite that may in the future have value as a source of furnace-grade phosphate rock. Several of the phosphatic shales above the pelletal beds contain unusual concentrations of vanadium, rare earths, and other elements. Many of these beds are so highly carbonaceous that freshly broken unweathered pieces readily smudge the fingers.

The lower limestone member is approximately 450 feet thick and consists of medium- to fine-grained, medium- to poorly-bedded, blue-gray, sandy or silty limestone that contains abundant nodules and stringers of black, gray and dark-brown chert. This unit contains very few fossils, except for rare cup corals and somewhat more common bryozoa.

The upper limestone member is composed principally of medium- to light-gray, medium- to well-bedded coquinoid limestone, but includes some beds of fine-grained silty limestone and medium-grained, brown-weathering sandstone. Both the coquinoid and the fine-grained limestone beds locally enclose large nodules of black chert. The sandstone beds are especially abundant in the northeastern part of the range.

The following fossils have been collected from the Deseret limestone in the East Tintic Mountains:

From the upper limestone member:

Timania? sp.
Auloporoid coral
Michelinia sp.
Crinoid columnals
Fistuliporoid bryozoan, incrusting type
Stenoporoid bryozoans, ramose forms
Fenestella sp.
Polypora sp.
Penniretepora sp.
Sulcoretepora sp.
Rhomboporoid bryozoans
Rhipidomella aff. R. dubia Hall
Spirifer sp. (group of S. bifurcatus Hall and S. washingtonensis Weller)

From the lower limestone member:

Cyathaxonia sp.
Stenoporoid bryozoan
Fenestella, several spp.
Polypora sp.
Ichthyorachis sp.
Penniretepora sp.
Sulcoretepora sp.
Spiriferoid brachiopod, undet.

From the basal phosphatic shale member:

Leiorhynchus carboniferum polypleurum Girty

Humbug formation

The Humbug formation was named by Tower and Smith (1899, p. 625-626) from exposures near the Humbug tunnels 1¼ miles southeast of Eureka. It consists of a rather uniform series of interbedded quartzitic sandstones and sand-streaked and pure limestones, with a few thin beds of dolomite, and one or more beds of reddish-brown shale. The sandstone beds range in thickness from 8 inches to 15 feet or more; they are most typically dark reddish-brown, medium- to coarse-grained, and many are cross-bedded. The limestone beds are 1 to 10 feet or so thick. They are fine- to medium-grained and medium- to light-blue; some are cherty, and others are coquinoid. On the whole the limestone beds resemble those of the Deseret and Great Blue limestones. The contacts of the Humbug formation are

gradational, and are arbitrarily placed at the base of the lowest sandstone bed, and at the top of the highest sandstone bed where sandstone is abundant in the Upper Mississippian section. Despite these rather indefinite boundaries the Humbug varies less than 100 feet in its total thickness, which averages 650 feet throughout the East Tintic Mountains.

Although many of the limestone beds of the Humbug contain abundant and well-preserved fossils none were collected since it lies between formations that are well dated as Late Mississippian. The Humbug formation has also been recognized in the Oquirrh Range (Gilluly, 1932, p. 26-29) where it contains fossils that have their closest affinities with the earlier faunas of the Brazer limestone.

Great Blue limestone

The Great Blue limestone conformably overlies the Humbug formation, and is about 2,500 feet thick in the East Tintic Mountains. In ascending order it includes a basal limestone member about 400 feet thick, a limestone and shale member about 650 feet thick, a shale and quartzite member 850 to 1,000 feet thick, and an upper limestone member about 600 feet thick.

The basal limestone member is prominently exposed at the abandoned Topliff quarry, and in many other areas in the North Tintic mining district. It consists entirely of limestone in well defined beds which range in thickness from 6 or 8 inches to 6 feet or more. Most of it is medium- to fine-grained, medium- to dark-gray and essentially free from sand and silt, but some beds locally carry scattered lenses of brown sandstone, and others contain nodules and thin layers of black chert.

The limestone and shale member consists mainly of limestone, but contains many beds of brown-weathering olive-green shale, and a few beds of medium-grained brown quartzite. The base is taken at the base of the first shale or shaly quartzite bed above the thick section of well-bedded limestone of the lower member. Many of the limestone beds in the limestone and shale member are argillaceous and weather brown, and some contain abundant nodules of dark-brown and black chert. The shale beds weather olive-green, tan

or brown, but are dark-green or dark-gray on the freshly broken surface.

The thick shale and quartzite member, which makes up from one-third to one-half of the Great Blue in the East Tintic Mountains, is prominently exposed in Chiulos Canyon. The shale beds, which are the dominant rock in the lower half of this member, are fine-grained, fissile, and range in color from sooty-black to greenish-gray. They are interlayered with thick beds of medium- to fine-grained, gray-green to brown, cross-bedded quartzite that become more abundant and increase in thickness upward, and are the dominant rock in the upper half of the member. Most of the quartzite beds and many of the shale beds are cut by narrow veins of milky quartz that are so widespread as to be useful in identifying this member.

The upper limestone member is composed almost entirely of limestone, but it commonly is not well exposed, inasmuch as it lies between thick units of shale that characteristically form strike valleys. The limestone is fine- to medium-grained, thin-bedded, and weathers gray to tan with coatings of silt and clay on the exposed surfaces. Much brown-weathering black chert is interlayered with the limestone and litters the surface near outcrops of the member. The contact of the upper limestone member of the Great Blue with the Manning Canyon shale is gradational; it is exposed in only a few places at Fivemile and Tenmile passes.

The Late Mississippian age of the Great Blue has been firmly established by Girty (Gilluly, 1932, p. 30-31) in the Oquirrh Range; consequently, only a few fossils were collected from the many fossiliferous limestone beds of the Great Blue in the East Tintic Mountains. These fossils include the following forms:

From the limestone and shale member 400 to 1,000 feet above the base:

Fistuliporoid bryozoans
<u>Ramiporalia</u>? sp.
<u>Fenestella</u> spp.
<u>Penniretepora</u> sp.
<u>Sulcoretepora</u> sp.
Rhomboporoid bryozoans
<u>Productus</u> sp.
<u>Linoproductus pileiformis</u> (McChesney) ?

Spirifer aff. S. arkansanus Girty
Spirifer aff. S. washingtonensis Weller
Cleiothyridina sublamellosa (Hall)
Composita sp.
Dielasma sp.

Although the Great Blue limestone of the East Tintic Mountains is not strictly comparable lithologically to the Great Blue limestone of the Oquirrh Range, the formation occupies the same stratigraphic interval and is considered to be directly correlative. The Long Trail shale member of the Great Blue in the Oquirrh Range is correlated on stratigraphic evidence with one or more of the shales of the limestone and shale member. The shale and quartzite member of the Great Blue limestone of the East Tintic Mountains is recognized near the southern terminus of the Oquirrh Range, but apparently lenses out before it reaches Ophir Canyon in the central part of the Oquirrh Range.

MISSISSIPPIAN AND PENNSYLVANIAN SYSTEMS

Manning Canyon shale

The Great Blue limestone is conformably overlain by the Manning Canyon shale which is approximately 1,050 feet thick. It consists of three members: 1) a lower member composed of fissile, brown-weathering black shale that contains many fossils, 2) a limestone member that is blue-gray, medium- to massive-bedded, fine-grained and essentially devoid of fossils, and 3) an upper member composed principally of black, brown-weathering shale but which includes many beds of dark-gray to black limestone, and several lenses of brown-weathering quartzite that intergrade along the strike with pebble conglomerate. The limestone member, which occurs near the middle of the formation, is about 80 feet thick at Tenmile Pass.

Large numbers of fossils were collected by Gilluly (1932, p. 32-34) from the Manning Canyon shale in the Oquirrh Range. These were determined by G. H. Girty to be in part of Late Mississippian age and in part of Early Pennsylvanian age. The boundary between the Mississippian and Pennsylvanian rocks is not precisely known, but is believed to be near the top of the formation.

PENNSYLVANIAN AND PERMIAN SYSTEMS

Oquirrh formation

The Oquirrh formation is prominently exposed in the northern and southern parts of the East Tintic Mountains, but neither area includes a complete or unfaulted section. The northern exposures make up essentially all of the Thorpe Hills and consist of the lower 4,500 feet or more of the formation. The Oquirrh-Manning Canyon contact is reasonably well exposed in this area. The southern exposures begin on the south side of County Canyon and extend southerly to the north side of Sandstone Gulch. More than 15,000 feet of beds were measured across these exposures, but the lower 500 feet or more of the formation is cut out by the County Canyon fault, and an undetermined but probably large thickness of beds also seems to be cut out by a strike fault in the upper third of the exposed section.

The relatively small part of the Oquirrh exposed in the Thorpe Hills is nearly identical with the equivalent section of rocks exposed in the Oquirrh Range; it consists of a lower limestone member 1,550 feet thick, and an overlying sequence of alternating quartzitic sandstones and arenaceous or argillaceous, fossiliferous limestones 3,000 to about 3,500 feet thick. The Oquirrh formation of the southern part of the East Tintic Mountains consists of about 1,000 feet of fossiliferous, well-bedded limestone at the base, approximately 8,500 feet of alternating quartzites and limestones between the basal member and the prominent fault, and 5,000 to 6,000 feet of cherty dolomite probably derived from the hydrothermal alteration of limestone. Only a few beds of quartzite and limy sandstone were recognized between the fault and the basal contact of the Diamond Creek(?) sandstone. The section of Oquirrh formation shown in figure 5 is a composite of the Oquirrh exposed in both the northern and southern parts of the East Tintic Mountains. In the nearby Gilson Mountains, and on Long Ridge north of State Highway 132 a short distance east of the area covered by plate 1, the upper part of the Oquirrh formation is largely limestone with a few intercalated beds of sandstone and comparatively little dolomite.

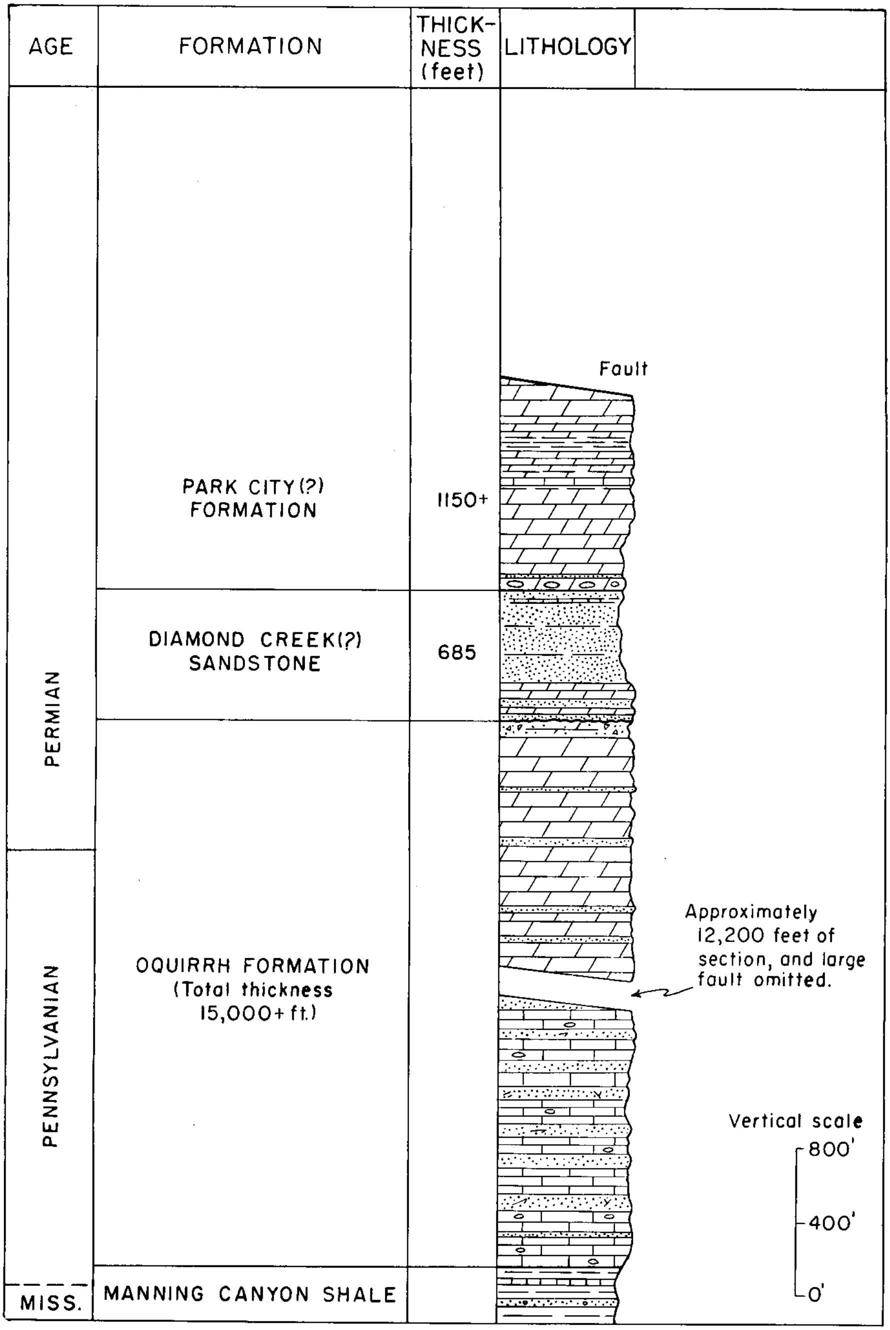

Figure 5. Columnar section of Pennsylvanian and Permian rocks

Disconformity at the top of the Oquirrh formation

The uppermost beds of the Oquirrh formation exposed in Sandstone Gulch consist of a thoroughly recrystallized angular breccia that appears to have been deeply weathered prior to the deposition of the overlying Diamond Creek(?) sandstone. At Kirkman Hollow in the southern Wasatch Range, about 50 miles northeast of Sandstone Gulch, the Oquirrh and Diamond Creek formations are separated by the Kirkman limestone which is 1,600 feet thick (Baker, 1947), but which thins rapidly to the west. The Kirkman is described by Baker and Williams (1940, p. 625-627) as a gray to black, in part finely laminated limestone that is interlayered with beds of angular breccia.

No beds resembling the dark laminated limestones of the Kirkman have been recognized immediately below the Diamond Creek(?) sandstone in the East Tintic Mountains, indicating that this area was pobably being eroded while Kirkman sediments were being deposited.

PERMIAN SYSTEM

Diamond Creek(?) sandstone

The beds provisionally correlated with the Diamond Creek sandstone of the southern Wasatch Range (Baker and Williams, 1940, p. 625-627) are about 685 feet thick, and consist mainly of buff and yellowish-gray, fine- to medium-grained, cross-bedded sandstone. The lower 200 feet of the formation includes several beds of gray hydrothermal(?) dolomite and many layers of red to purplish-red conglomeratic mudstone.

The upper part of the Diamond Creek(?) is composed almost wholly of weakly cemented, subangular to subrounded frosted quartz grains arranged in prominent cross-beds. The uppermost beds are somewhat more firmly cemented than the beds immediately below.

No fossils have been found in the Diamond Creek(?) sandstone in the East Tintic Mountains, but its close lithologic similarity to the Diamond Creek sandstone of the Wasatch Range, and to the Coconino sandstone of the San Rafael Swell suggests that the formations are correlative.

Park City(?) formation

The Diamond Creek(?) sandstone is conformably overlain by a sequence of cherty limestones and hydrothermal dolomites, 1,150 feet thick that closely resemble the beds of the Park City formation of nearby areas. These are the youngest Paleozoic rocks exposed in the East Tintic Mountains. The Park City(?) is gradational with the Diamond Creek(?) through a thickness of 50 to 100 feet, but the base of the Park City(?) is placed at the top of the uppermost thick sandstone of the Diamond Creek(?). The top of the Park City(?) is cut out along a fault of enormous stratigraphic displacement that repeats the lower part of the Oquirrh formation.

The Park City(?) formation consists chiefly of hydrothermal dolomite, and contains only poorly preserved fragments of fossils. The brachiopod **Wellerella** cf. **W. osagensis** (Swallow) was identified, but this species ranges through Pennsylvanian and Permian and is not restricted to rocks of Park City age.

TERTIARY SYSTEM

Eocene series

Unnamed conglomerate

At many places the middle Eocene volcanic rocks of the East Tintic Mountains and the structurally deformed Paleozoic rocks are separated by an irregular thickness of coarse conglomerate. This conglomerate consists of subangular pebbles, cobbles and boulders of quartzite, dolomite, limestone and shale firmly cemented in a brick-red, calcareous matrix. These deposits apparently occur in pre-lava gullies and valleys, and the angularity and poor sorting of the fragments suggests that they were deposited as colluvium or talus.

Pliocene series

Salt Lake(?) formation

Deposits of fanglomerate, gravel, silt, marly limestone, and bentonitic tuff, which are provisionally correlated with the Salt Lake formation of Pliocene age exposed about 20 miles south of Salt Lake City at Jordan Narrows (Hunt,

Varnes, and Thomas, 1953, p. 13-14, and Slentz, 1955), crop out over wide areas in Rush and Tintic Valleys. Similar deposits are also presumed to underlie Pleistocene lake beds or detrital deposits in Cedar, Goshen and other valleys adjacent to the East Tintic Mountains. All of these deposits have been studied only incidentally, and not in the detail warranted by their importance.

The Tertiary deposits are poorly consolidated, and, where weathered, cannot be readily distinguished from adjacent and overlying Pleistocene and Recent deposits. However, the bentonitic tuffs and limestone beds crop out somewhat more prominently than the other units of Tertiary age, and their general ares of outcrop are shown on plate 1. The limestones are especially well exposed in railroad and highway cuts, and along gullies near Boulter Pass. They are medium-bedded to massive, and weather chalky-white, being grayish- to creamy-white on fresh fractures. Some beds contain moderately well preserved shells of spired gastropods, and ostracode shells identified for H. D. Goode by I. G. Sohn (written communication, 1955) as being **"Candona"** or related genera. The bentonitic tuffs are interlayered with the marly limestones but crop out less prominently. On a freshly broken surface they are pale grayish-green in color and dense, texturally resembling bar soap. Small flakes of lustrous black biotite are readily identified with a hand lens, but the feldspar fragments and the original matrix of vitric shards are altered to clay. The weathered exposures of the bentonitic tuff beds are characteristically a loose, fluffy soil.

Near Boulter Pass the limestone and bentonitic tuff beds strike almost due north and dip east at 14° to 22°. However, approximately 9 miles northwest of Boulter Pass, beyond the area covered by plate 1, dips of 35° to the west were observed in similar beds. No folds or structures related to folding were observed in the marlstones and bentonites, and it is believed that the large and diverse dips are the result of the tilting and displacement of the valley fault blocks that took place during the early part of the Pleistocene epoch. Owing to the possible repetition of beds by faulting no estimates of the total thickness of the bentonitic tuff and marly limestone section were made.

The limestone and bentonitic tuff beds are overlain by a thick unit of reddish-brown silt which is essentially uncon-

solidated, but which displays the same structural relations as the underlying beds. This silt deposit is in turn unconformably overlain by fanglomerate that extends westward from the East Tintic Mountains as alluvial fans. These fans retain their original topographic characteristics, and thus are presumed to be of Pleistocene age. To the west the limestone and bentonitic tuff deposits appear to interfinger with silt, gravel and fanglomerate deposits that constitute extensive exposures of the Salt Lake (?) formation on the west side of Tintic Valley.

The beds of the Salt Lake(?) formation that underlie the west half of Tintic Valley are beveled by a dissected pediment surface that slopes to the southeast at 3° to 5°. This pediment surface is covered by an irregular thickness of gravel composed chiefly of subangular and subrounded fragments of Precambrian rocks derived from the Sheeprock and West Tintic Ranges.

The east side of Tintic Valley between Diamond Gulch and Jericho Pass is underlain by a broad bajada that may have developed chiefly in late Tertiary time, but which also contains deposits of probable Pleistocene and Recent age.

The age of the marly limestone and bentonitic tuffs is not fixed with any certainty, but is estimated by Sohn (written communication to H. D. Goode, 1955) to be early Pliocene or older. This assignment is based on comparisons of the amount of the noncarbonate residue of the ostracode shells found in the limestone beds with the amount of the noncarbonate residue of somewhat similar shells of known Pliocene age from Malheur County, Oregon, and other areas. According to Sohn the age determination may not be as accurate as inferred.

The marly limestones in the northeast part of the area covered by plate 1 near the Fox Hills are similar to the marly limestones of the Salt Lake (?) formation, but may not be of Pliocene age, inasmuch as these beds underlie basalt flows that are probably related to the Eocene volcanism of the main East Tintic Mountains. Similar limestones exposed in the west-central part of Long Ridge are interbedded with latite agglomerate, and contain Eocene (Green River) fossil plants (see page 29).

QUARTERNARY SYSTEM

Unconsolidated deposits of Quaternary age underlie broad areas of the larger valleys that border the mountains, and extend into the larger gulches that cut the consolidated rocks. The oldest deposits are pre-Lake Bonneville fanglomerate and loessic silts. At elevations below 5,135 feet, which includes large parts of Rush, Cedar and Goshen Valleys, these beds are overlain by gravels, sands and silts deposited in glacial Lake Bonneville during the Wisconsin stage.

The youngest deposits exposed in the East Tintic Mountains consist of talus, colluvium, alluvium, and eolian sands and silts.

Igneous rocks

GENERAL STATEMENT

The East Tintic Mountains are the deeply eroded remnant of a large composite volcano that essentially buried a pre-existing, structurally complex mountain range. The principal eruptive centers of this volcanic pile are now marked by stocks, plugs, and dikes that occur approximately in the center of the range.

The effusive rocks of this volcanic pile are subdivided into three groups: 1) an early sequence of quartz latite tuff and flows (the Packard and Fernow quartz latites), 2) an intermediate sequence of latite (and possibly andesite) tuffs, flows and agglomerate, and 3) a late sequence of basalt flows. The intrusive stocks, plugs, and dikes are composed of quartz monzonite, monzonite, monzonite porphyry, latite porphyry, and diabase. A sill and a dike that have the general mineralogic composition of quartz monzonite, but the typical texture and glistening appearance of a lamprophyre, cut Upper Mississippian limestones at the west edge of the range between Mill and Black Rock Canyons.

The age of the latite and andesite volcanic series has been determined to be middle Eocene, on the basis of plant fossils found by Siegfried Muessig (1951, p. 234) in marly limestones interbedded with agglomerates exposed in the middle fork of Sage Valley, at the southern tip of Long Ridge 30 miles south-southeast of Eureka. Tuffaceous sediments similar in composition to the fine-grained pyroclastic rocks of the East Tintic Mountains are also inter-

bedded with shale and sandstone of the Green River formation in road cuts on U. S. Highway 91 southwest of Levan, Utah. Radioactive zircons separated from monzonite of the Silver City stock, and from a plug of quartz monzonite porphyry near the North Lily mine, a mile northwest of Dividend, were also determined to be of middle Eocene age (46.5 and 38 million years old) by Howard Jaffe of the U. S. Geological Survey (written communication, 1954; report no. IWM 629).

The basalt flows of the northeastern part of the East Tintic Mountains are underlain by limestone. Their tentative correlation by Bullock (1951, p. 20) with the Salt Lake formation indicates a Pliocene age or younger. However, it is equally possible that these beds may be of middle Eocene age, and correlative with the limestone beds exposed in Sage Valley.

EXTRUSIVE ROCKS

Packard quartz latite and Fernow quartz latite

The oldest effusive rocks currently recognized in the East Tintic Mountains were named the Packard rhyolite by Tower and Smith (1899, pl. 74) from extensive exposures at Packard Peak. A closely similar effusive rock that crops out in the southern part of the range was named the Fernow rhyolite (Tower and Smith, 1899, pl. 74) for exposures near Ferner Valley. Recent studies have shown that the Packard and Fernow are evidently parts of the same volcanic series which have been separated geographically by overlying latite volcanic rocks. Both the Packard and Fernow lavas contain approximately as much plagioclase as orthoclase (sanidine), in addition to quartz and other constituents, and thus have the composition of quartz latite, the designation which is given them in this report.

The Packard is subdivided into four units: 1) a basal tuff, 2) a lower vitrophyre, 3) a massive flow unit, and 4) an upper vitrophyre. The basal tuff is a few inches to perhaps as much as 100 feet thick, but is absent in many areas. It is chiefly fine-grained, but locally contains fragments to 2 inches or more in diameter. Because of its high porosity and its position at the base of the volcanic series, the tuff

was extensively altered by hydrothermal solutions at many localities.

The lower vitrophyre ranges from a few feet to perhaps 700 feet or more in thickness, and like the tuff is locally absent. Where it has not been devitrified by hydrothermal solutions it is a lustrous black obsidian that encloses well-formed phenocrysts of biotite and sanidine, and partly resorbed phenocrysts of quartz. Close to hydrothermal conduits the vitrophyre has been partly devitrified and resembles a fine-grained biotite-quartz latite, and has been mistaken for a separate flow.

The massive quartz latite flow unit of the Packard is a few feet to more than 2,300 feet thick. This great variation in thickness is in part the result of deposition on a surface of strong relief that was only moderately smoothed out by the earlier tuffs and vitrophyre flows, and in part the result of intermittent movement that occurred on some faults during the eruption of this member. Prominent features of the massive flow rocks of the Packard quartz latite in the central part of the range are faint but distinct, contorted flow-folds of large magnitude that leave little doubt that the rock was once molten. Hand specimens of the flow rocks are medium-grained and dense; they range in color from pinkish-gray to smoky-lavender and blue-gray. Phenocrysts of sanidine, andesine, quartz and biotite make up 20 to 50 percent of the rock. A little hornblende is present in some flows, and magnetite, apatite and sphene are common accessory minerals. The massive Packard quartz latite exposed in the northeastern part of the East Tintic Mountains is nearly identical with the Fernow quartz latite described below.

The upper vitrophyre unit of the Packard quartz latite closely resembles the lower vitrophyre unit, but near the top is agglomeratic and contains one or more beds of fine- to medium-grained tuff.

The Fernow quartz latite exposed near Ferner Valley consists of a basal tuff bed of irregular thickness, and an overlying unit of vitrophyre or porphyritic quartz latite lava. The basal tuff ranges in texture from fine grained to coarsely fragmental, and at many exposures merges imperceptibly with the overlying unit. Hand specimens of the

vitrophyre are medium to light pinkish-gray, and contain prominent phenocrysts of quartz and sanidine, and sparse phenocrysts of biotite, all embedded in a matrix of light- to medium-gray obsidian. Many of the quartz phenocrysts are stubby, bipyramidal crystals slightly rounded through incipient resorption. Most of them are also clear but dark, and closely resemble the smoky quartz phenocrysts of the Packard quartz latite. The less glassy varieties of the Fernow have a dense, aphanitic matrix but otherwise are similar to the vitrophyres. Even the most lithic Fernow lavas commonly contain streaks of glassy material a few inches long that appear to be flattened, rather than drawn out in flow bands. The general absence of flow banding is conspicuous, and may indicate that the greater part of the Fernow quartz latite, as well as the massive lavas of the Packard exposed just south of Wanlass Hill in the northeastern part of the range, are welded tuffs rather than flow rocks.

Latite volcanic series

The latite effusives, which disconformably overlie the rocks of the Packard quartz latite, exhibit a wide range of textures but are all similar in composition; thus these rocks are believed to be the product of only one general series of volcanic eruptions. They are subdivided into five units: 1) a basal tuff, 2) a lower flow series, 3) an intermediate tuff and agglomerate, 4) an upper flow series, and 5) a thick and extensive agglomerate.

The basal tuffs are thickest near Ruby Hollow and Diamond Gulch, but they occur at nearly every exposure of the lower latite flow unit in the East Tintic Mountains. The tuffs are both fine- and coarse-grained, and in some areas are agglomeratic. Fragments of Tintic quartzite and post-Tintic carbonate rocks and shale are common in them, and probably were ejected along with the volcanic material. Where the basal tuffs have not been altered by late hydrothermal solutions, they range in color from gray-green to purplish- or reddish-gray, but near the ore-producing centers they are dazzling white, with local zones stained red and brown by iron oxides, or gray to black by manganese minerals.

The lower flow unit is a few feet to 1,000 feet or more thick, and is especially well exposed on Flatop Mountain 2

miles northeast of Eureka, and in Pinyon Creek Canyon. It is composed chiefly of dark gray to black, coarsely porphyritic latite, but in many areas it includes near the base one or more thick flows of red to reddish-brown latite of nearly identical texture. The lowest flow is commonly a black vitrophyre. Phenocrysts make up 10 to about 30 percent of these rocks, and consist of orthoclase, plagioclase (calcic oligoclase to labradorite), hornblende, biotite, augite, magnetite, and quartz. Hypersthene occurs instead of hornblende in some flows. Examination of thin sections under the microscope showed that much of the quartz represents partly digested fragments of the Tintic quartzite. The groundmass of the rock is fine-grained to glassy, and the phenocrysts embedded in it define a prominent planar structure.

The intermediate tuffs and agglomerates are similar to the tuffs of the lower unit, and in some places where the lower flows are absent, cannot be distinguished from them. In general, however, they are coarser, and locally contain masses of igneous rock 6 to 8 feet in diameter enclosed in a matrix of fine- to coarse-grained pumiceous breccia.

The upper flow series consists chiefly of coarse-grained latite, but possibly includes one or more flows of andesite and trachyandesite. The typical rock is conspicuously porphyritic, and contains phenocrysts of biotite and strongly zoned andesine or labradorite; sanidine may or may not be abundant. Augite is the dominant pyroxene, but in some flows hypersthene is also present; hornblende is rare, and quartz is essentially absent. Magnetite is abundant in all flows of this unit; some flows contain such a large proportion that they strongly affect the compass needle. The groundmass is medium-grained to glassy, and near the tops of some flows the rock is vesicular.

The agglomerate unit is the most widespread of the latite volcanic rocks. It covers broad areas of the northeastern and southeastern parts of the East Tintic Mountains and large parts of Long Ridge and adjoining regions. It consists of a heterogeneous assemblage of angular to subrounded fragments of latite ranging from silt-sized particles to huge blocks of lava weighing several tons. The deposits are poorly stratified, and weather to rounded slopes covered by lava boulders.

Basalt

The basalt flows in the northeastern part of the East Tintic Mountains are fine- to medium-grained porphyritic, and nearly black in color. The phenocrysts are 5 millimeters (0.2 inch) or less in length and consist of labradorite, augite and olivine; magnetite and apatite are common accessory minerals. The rock is most commonly vesicular, but it ranges from dense to scoriaceous.

INTRUSIVE ROCKS

Swansea quartz monzonite stock

The Swansea quartz monzonite stock was named by Smith, Tower, and Emmons (1900, p. 2) for the Swansea mine 1⅓ miles southwest of Mammoth. The main mass of quartz monzonite is nearly 0.8 of a mile long and 0.3 of a mile wide; it extends from Mammoth Gulch to Dragon Canyon at the west-central edge of the range. A smaller mass crops out south of Mammoth, and a dike of similar rock cuts the Tintic quartzite on Quartzite Ridge. Other dikes have been penetrated by workings of the Centennial Eureka, Eagle and Bluebell, and other mines a short distance south of Eureka.

The typical rock of the Swansea stock is fine- to medium-grained. The texture ranges from granitic to porphyritic; however, it is coarsely porphyritic in dikes. The prevailing color of the freshest material is pale grayish-pink, but most of it is gray-green owing to chloritic alteration, or buff to white as a result of the weathering of disseminated pyrite of hydrothermal origin. The dominant minerals are quartz (30 percent), sodic andesine (35 percent), orthoclase (27 percent), biotite (5 percent), and hornblende (2 percent). Magnetite, apatite, and zircon are accessory minerals.

The quartz monzonite of the Swansea stock is nearly identical in chemical and mineralogical composition with the Packard quartz latite, and thus is probably distinctly older than the monzonite of the Silver City stock, which is similar in chemical and mineralogical composition to the latite volcanic series. The Swansea stock is also cut by short apophyses of the Silver City stock, and the monzonite also displays a fine-grained, chilled edge against it.

Lamprophyre dike and sill

A dike and sill of lamprophyre (possibly kersantite but with important amounts of quartz and microcline) are poorly exposed a short distance south of the mouth of Black Rock Canyon. The dike is localized along a fault; it is about 300 feet long and 50 to 75 feet wide. The sill is approximately ⅔ mile long and 5 to 25 feet thick; it occurs near the base of the Great Blue limestone. In hand specimen the rock is prominently porphyritic with well formed books of biotite and poorly developed phenocrysts of argillized feldspar, which is believed to be andesine or labradorite, embedded in a dusty, gray-green, microgranular groundmass. Under the microscope biotite and apatite are readily identified, but the feldspar phenocrysts are so poorly formed and so highly altered that identification is difficult. Quartz, microcline, and brown calcite can be identified in the groundmass, but most of the matrix of the rock is altered to clay. Mineralogically the lamprophyre is more nearly related to quartz monzonite than to monzonite, but on the basis of the limited geological and mineralogical evidence at hand a specific correlation with the quartz monzonite of the Swansea stock is not possible.

Monzonite porphyry of Sunrise Peak and related rocks

A stock of dark-gray to greenish-gray monzonite porphyry underlies Sunrise Peak south of Diamond, and extends northward to the south edge of Ruby Hollow. Similar rock occurs as a plug nearly concealed by alluvium in Eureka Gulch near the intersection of Church and Main Streets in Eureka, and as a body of unknown size cut by the 700 level of the Sacramento shaft in the lower part of Cole Canyon 3/4 mile west of Eureka. The typical specimen of monzonite porphyry from the Sunrise Peak intrusive is dense and porphyritic, with phenocrysts constituting about 30 percent of its volume. The phenocrysts consist chiefly of andesine, biotite, and augite; smaller crystals of orthoclase, magnetite, and apatite are also present in the groundmass.

The monzonite porphyry of Sunrise Peak and related rocks closely resemble the flow rocks of the latite volcanic series in texture and composition, and probably represent shallow intrusives derived from the same general magma.

Latite plugs and dikes

Near the Independence (Silver Shield) shaft 4½ miles east-northeast of Eureka the Packard quartz latite and the overlying latite tuff-breccias are cut by a dike approximately 150 feet wide and 1½ miles long that extends eastward to a point where it merges with a thick latite flow. Other plug-like bodies of the same rock occur ½ mile north of the dike, and in the upper part of Pinyon Creek Canyon near the keyhole-shaped bend in the railroad. The rock is compact, medium to dark greenish- or brownish-gray, and prominently porphyritic; the phenocrysts are calcic andesine, hornblende, and biotite. In thin sections of this rock, sanidine, augite, and minor quartz are readily identified in the groundmass along with magnetite and apatite. These dikes and plugs doubtless served as feeders to the latite flows in the general area, and were probably derived from magmas from the same general source as the monzonite porphyry of Sunrise Peak.

Silver City monzonite stock

The Silver City monzonite stock was named by Loughlin (1919, p. 64) from exposures near the townsite of Silver City. The name is strictly applied to the intrusive body that extends south from Mammoth Gulch to Ruby Hollow, and from the west edge of the range eastward to a line drawn roughly from the head of Dragon Canyon to Silver Pass. However, many dikes, plugs, and small stocks of closely similar mineralogic composition occur in a zone about ½ to 1½ miles wide extending 3½ miles north-northeasterly through the East Tintic mining district from the area of Silver Pass to the Homansville fault. These smaller intrusives, however, are somewhat more porphyritic, and are given other local names not used in this report.

Hand specimens of unaltered monzonite from the western half of the Silver City stock are medium to light purplish-gray and medium- to fine-grained granular; specimens from the eastern half of the stock are less equigranular, and many are distinctly porphyritic. The minerals identified in thin sections of the rock include: andesine (30 percent); orthoclase (30 percent); quartz (5 percent or slightly higher); augite (15 percent); hornblende (10 percent); biotite

(7 percent) ; magnetite, apatite, zircon, and sphene (total of 3 percent). Most of the ferromagnesian minerals are altered to aggregates of chlorite, clay minerals, and calcite.

The average intrusive rock found in the zone of plugs and dikes that extends through the East Tintic mining district is distinctly porphyritic and contains phenocrysts as much as 4 millimeters (about 0.15 inch) long in a groundmass of microgranular to granitic texture. The rock ranges in composition from quartz monzonite to basic monzonite, but seems to be the product of the same general magma. The average rock is probably typified by specimens from small plugs exposed in Burriston Canyon 1¼ miles southwest of Dividend. The rock from these plugs is holocrystalline porphyritic; the phenocrysts consist of andesine, sanidine, quartz (5 percent or less), biotite and augite in nearly equal amounts, hornblende, and minor accessory minerals. Specimens from some of the plugs a mile northwest of Dividend near the North Lily mine contain moderately abundant phenocrysts of quartz, but many of these so-called "phenocrysts" are seen under the microscope to be small, rounded and embayed xenoliths of quartzite, probably derived from the Tintic quartzite. The more basic monzonite porphyry dikes contain less quartz and orthoclase, and more andesine than the average rock; the andesine is also somewhat more calcic.

The contact of the Silver City monzonite stock with the sedimentary rocks is marked by irregular apophyses that cut the limestone along faults, bedding planes, and joints in a manner that strongly suggests magmatic stoping as the principal method of emplacement of the main monzonite mass. Numerous rotated xenoliths of shale, quartzite, and limestone aligned within the stock more or less on projection of their expected pre-intrusive position are further evidence of a quiet mode of emplacement. In contrast, the walls of many of the smaller dikes and plugs in the East Tintic district are commonly shattered, which may indicate that these bodies were abruptly and forcibly emplaced. The close association of pebble dikes with these intrusives further indicates that some of the plugs may have been explosively injected into the country rock.

Pebble dikes

Dike-like bodies consisting chiefly of rounded, angular or subangular fragments of Tintic quartzite with some disk-shaped fragments of shale are common within or near the belt of intrusive rocks that extends through the East Tintic district. They range from a foot or so to several hundred feet in length and from a fraction of an inch to several feet in width. Some are typically dike-like, and have been traced downward into dikes of monzonite porphyry, but others apparently occur as discrete lenses that seem to have no roots. Irregular envelopes of pebble-dike material enclose some monzonite porphyry dikes, but most of the pebble dikes are not closely associated with monzonite dikes, and contain no monzonite porphyry either as fragments or as associated intrusive material.

The pebbles range in size from a fraction of an inch to as much as 10 inches in diameter. The quartzite pebbles, which constitute more than 90 percent of the megascopic fragments, commonly are almost spheroidal, and with the less well-rounded fragments of shale and, rarely, other rocks, are embedded in a matrix of quartz and carbonate rock-flour. Most of the quartzite pebbles show a concentric spall or onion-skin structure parallel to the outer surface. This structure is not seen on the shale and limestone fragments, and is probably related to the relatively larger coefficient of thermal volumetric expansion of quartzite.

Some of the pebble dikes apparently were emplaced by the sudden upwelling of viscous monzonite magma, but most of them seem to have been exploded into place by rapidly expanding gases, perhaps composed chiefly of steam generated by the instantaneous heating of groundwater by invading monzonite magma, in individual explosions triggered by tensional fault adjustments. This mode of emplacement has been descriptively though inelegantly termed a volcanic burp.

Biotite-augite andesite dikes ("purple porphyry")

Highly altered dikes of biotite-augite andesite porphyry, which have not been observed at the surface, cut quartz monzonite dikes and ore in the North Lily mine ¾ mile northwest of Dividend, and sedimentary rocks and ore in the

Chief No. 1 mine, which is near the center of the south boundary of Eureka townsite. The freshest dike material occurs near the Leadville fault on the 1800 level of the Chief No. 1 mine; it is medium- to fine-grained and faintly porphyritic and contains phenocrysts less than 5 millimeters (about 0.2 inch) long embedded in an aphanitic groundmass. Under the microscope the phenocrysts were found to consist of andesine, augite, and biotite; no quartz or othoclase was recognized. The constituents of the groundmass are so exceptionally fine-grained they could not be identified; they may represent a devitrified glass. In contrast to this fresh rock, the average dike material consists almost entirely of kaolinite, halloysite, and siderite, which preserve the porphyritic texture of the rock. The prevailing purplish- or reddish-gray color of the altered rock is due to finely disseminated hematite, probably derived through the alteration of original magnetite.

In both the North Lily and Chief No. 1 mines "purple porphyry" dikes occupy east-trending fractures in contrast to the ore bodies which more or less follow north- and northeast-trending faults and fissures. They distinctly cut some ore bodies, but locally at some crossings they are themselves weakly replaced by sulfide minerals. Ores on the 2600 level of the Chief No. 1 mine, and reportedly also in the North Lily mine, are higher in grade on one side of a "purple porphyry" dike than the other. These relations suggest that the dikes were emplaced during the latter part of the interval during which the ore bodies were being deposited, and that they may have acted as impermeable barriers to the latest ore-depositing solutions that were rising from depth.

Diabase dikes and sills

Dikes and sills of diabase cut sedimentary rocks in the northern part of the East Tintic Mountains, and the volcanic rocks of the latite series in the southern part of the range. They are believed to be the youngest of the intrusive rocks, but are not found near the quartz monzonite and monzonite stocks and consequently are not well dated in refererence to these rocks. The typical diabase is dark greenish-gray to black, and ranges in texture from aphanitic to strongly diabasic. In thin section the coarser-grained rock

is seen to be composed of phenocrysts and microcrysts of green olivine, augite, and magnetite embedded in a felted matrix of lath-shaped crystals of labradorite. Apatite is a common accessory mineral.

The diabase dikes and sills in the north-central part of the range are as much as 300 feet long and 50 to 75 feet wide, and may have been the feeder dikes for the basalt flows that crop out near Greeley Hill and the Mosida Hills.

STRUCTURE

GENERAL STATEMENT

The East Tintic Mountains are near the eastern border of the Great Basin, and are a typical north-trending range of the Basin and Range structural and physiographic province. The general form of the range strongly suggests an origin through massive but relatively simple block-faulting; however, the internal structures of the range record a history of complex structural development that considerably antedates the block-faulting.

The structure of the northern third or more of the range is dominated by north-trending anticlines and synclines which are superposed on the north flank of a broad, east-trending uplift whose axis extends through the range at about the latitude of Tintic Mountain. Much of the geologic structure in the south-central and eastern parts of the range is hidden beneath the extensive lava field, but scattered exposures of the sedimentary rocks between Copperopolis Canyon and Jericho Pass indicate that the Paleozoic strata in general dip to the south, and are tremendously thick in the southern part of the range.

The folded strata are cut by many thrust and strike-slip faults that apparently were created by the same compressive forces that produced the folds, and also by two or more transverse normal faults that originated during a later period of crustal tension.

Large normal faults are exposed locally near the margin of the range, but faults of the magnitude and persistence usually attributed to "Basin and Range" faults are known only conjecturally or from gravimetric data.

FOLDS

North Tintic anticline

The most persistent and prominent fold in the East Tintic Mountains is the North Tintic anticline, which is aligned with the Ophir anticline of the Oquirrh Range. The axis of the North Tintic anticline extends under the alluvium of Tintic Valley a few miles west of Eureka, but can be traced across the divide between Iron and Broad canyons. It is mostly concealed beneath the alluvial fill of Broad Canyon and Twelvemile Pass, but is again exposed where it crosses Topliff Hill.

South of Twelvemile Pass the North Tintic anticline is strongly asymmetric with a moderately dipping western limb, and a steeply dipping eastern limb that is locally overturned from Mammoth Gulch northward for about 9 miles. The strata exposed in the western limb dip to the west at approximately 30°, but close to the crest of the anticline have been folded into several minor anticlines and synclines whose axes are more or less parallel to the principal axis of the fold. At its southernmost exposures the trend of the main anticlinal axis is almost due north, but it diverges progessively to the west as it extends northward, and is about N. 40° W. across Topliff Hill. The axial plunge is to the north, and decreases from about 45° in the area between Broad and Iron canyons to about 15° near Topliff Hill.

As all the stratigraphic units from the Precambrian Big Cottonwood(?) formation to the Pennsylvanian and Permian Oquirrh formation are exposed along the axis or on the limbs of the North Tintic anticline an amplitude of more than 16,000 feet is indicated.

Tintic syncline

The Tintic syncline occupies the north-central part of the East Tintic Mountains, and is the principal structural feature in the Main Tintic mining district. The axis of this fold is displaced by several transverse strike-slip faults as is the axis of the North Tintic anticline, but can be traced from the edge of the Silver City monzonite stock at the head of Dragon Canyon northward to the edge of the

Packard quartz latite near the May Day mine a mile east-southeast of Eureka. The axis probably reappears north of the lava blanket on the first ridge southeast of Chiulos Canyon, but its actual position in this area is subject to some doubt owing to the appearance of a number of minor anticlines and synclines in the wide trough of the fold.

The western limb of the Tintic syncline corresponds to the steep-to-overturned eastern limb of the North Tintic anticline. South of Mammoth Gulch, however, part of this limb has been faulted up from near the axial area of the fold by the Sioux-Ajax fault, and the beds strike northwesterly and dip to the northeast at only 10° to 30°. Part of the eastern limb of the Tintic syncline is exposed in Burriston Canyon two miles southeast of Eureka, and probably also in the general area of Pinyon Peak. The average dip of this limb is 30° to the west.

The beds of both limbs of the Tintic syncline locally have been further folded into several smaller folds. Some of these minor folds are drag folds that were formed during the development of the major syncline, whereas others are localized near faults and seem to be drag folds of the friction type related to near-horizontal strike-slip movement on the faults. Several of these minor folds localize ore bodies of some importance, as for example, the drag fold in the American Star sector of the Chief No. 1 mine.

The axial zone of the Tintic syncline has been penetrated by many workings on the 1800 level of the Chief No. 1 mine. On this level of the mine the beds flatten abruptly from average dips of 80° east to 5° to 15° or so north, and east-west cross sections through the fold show it to have a wide, nearly flat trough. The gently undulating, north-dipping beds in the trough indicate that the fold plunges to the north at about 15° to 20° in this area. The axial plane of the fold dips moderately to the west, but calculations of the actual dip of the axial plane are not reliable owing to intervention of locally overturned beds, drag folds, and faults between the trace of the axial plane at the surface and the 1800 level of the Chief No. 1 mine.

The youngest rocks exposed in the trough of the Tintic syncline consist of the lower beds of the upper limestone member of the Upper Mississippian Great Blue limestone;

they are exposed near the head of Cedar Valley. The oldest rocks exposed on the limbs of the fold consist of the lowermost beds of the Lower Cambrian Tintic quartzite; they crop out on the west side of Quartzite Ridge at the west edge of the range. The stratigraphic interval between these beds indicates that the amplitude of the fold is more than 12,500 feet.

East Tintic anticline

The East Tintic anticline borders the Tintic syncline on the east and underlies the greater part of the East Tintic mining district. The folded beds are mostly concealed beneath volcanic rocks, but the west limb and axial area of the anticline are fairly well known from scattered surface exposures and mine openings, and part of the east limb has been penetrated by a few deep drill holes. The anticline is broken by many faults, but the trace of the axial plane can be safely inferred to underlie Silver Pass Gulch as far north as the Eureka Standard fault, which follows the lower part of Burriston Canyon 2 miles southeast of Eureka. North of Burriston Canyon the axis follows a sinuous course, but in general extends northward beneath the lava from the vicinity of the Eureka Standard shaft to the Homansville fault in Pinyon Creek Canyon, passing about 1,200 feet east of the Tintic Standard No. 2 shaft at Dividend. North of Pinyon Creek Canyon the East Tintic anticline is not clearly recognized, and in the high hills north-northeast of Pinyon Peak the beds are gently undulating and only broadly define an anticlinal structure.

Where it is best exposed in the central part of the East Tintic district, the East Tintic anticline has the general form of an undulating anticlinal dome that plunges to the north and south from a point approximately east of Dividend. Near the crest of the fold the moderately dipping western limb has been interrupted by a series of small asymmetric anticlines and synclines comparable to the small folds near the crest of the North Tintic anticline. These anticlines and synclines trend north-northwesterly and apparently are related to local reverse and thrust faults that are localized near the contact of the Tintic quartzite with the Ophir formation. One of these minor synclines has been cross-folded by a northeast-trending syncline, and forms the "pothole"

structure in the surface of the Tintic quartzite that localizes the famous Tintic Standard ore body.

The rocks that form the East Tintic anticline are chiefly Cambrian and Ordovician limestones, but the Lower Cambrian Tintic quartzite is exposed at the surface close to the crest of the anticline a short distance north of Dividend. The amplitude of the fold is probably not as great as that of the North Tintic anticline.

Folds in the northeastern sector of the East Tintic Mountains

In the northeastern part of the East Tintic Mountains the Devonian and Mississippian rocks, which lie chiefly northwest of the major northeast-trending transverse strike-slip fault that may be traced to Davis Canyon a mile and a half south of Paymaster Hill, are gently wrinkled by several small anticlines and synclines with wave lengths of a mile or less. These folds trend northward, and probably occur on the prolongation of the Long Ridge anticline of the Oquirrh Range. This correlation assumes that the major syncline of the Lake Mountains is in structural continuity with the Bingham syncline as proposed by Bullock (1951, p. 23). Other minor folds occur farther to the southwest, and are related chiefly to the overturning of beds beneath thrust faults.

Folds in the Southern Part of the East Tintic Mountains

The structure of the sedimentary rocks in the southern part of the East Tintic Mountains is not well known, but apparently is essentially homoclinal. The formations in general strike eastward, but range in strike from N. 45° W. to N. 45° E.; the dips are more uniform and range from 40° to 70° southward.

OVERTHRUST FAULTS

General statement

The overthrust faults exposed in the East Tintic Mountains are closely related, at least in origin, to the folds. Structural cross sections through the range suggest that these thrusts developed originally as bedding plane thrusts

that later cut the planes of stratification as the folds were intensified and overturned. Some of the thrusts are themselves folded.

With one exception the thrust faults dip to the west and the upper plate overrode the lower plate from the west. The displacements along these thrust faults are small compared to the displacements along the Nebo and Sheeprock thrust faults of the Wasatch Range and West Tintic Mountains, but the general characteristics of the faults are similar.

Allen's Ranch thrust fault

The largest thrust fault recognized in the East Tintic Mountains has been given the name Allen's Ranch thrust fault by Proctor (written communication, 1951) from exposures in the Allen's Ranch quadrangle. This thrust fault is exposed in the northeastern part of the range in the eastern parts of secs. 15 and 22, T. 9 S., R. 2 W. The northern termination of the fault is concealed by colluvium and agglomerate, but the thrust plane apparently stops against a northeast-trending strike-slip fault a short distance north of the point where it is last seen. From this area the fault has been traced at the surface southward for about 1½ miles to the edge of the volcanic rocks. Several northeast-trending strike-slip faults cut the upper plate of this thrust, and one also cuts the lower plate. The stratigraphic displacement along the Allen's Ranch thrust fault ranges from about 1,700 feet near the northernmost exposures to about 3,000 feet near the southernmost exposures, and increases as each strike-slip fault is crossed. The fault plane dips to the west at a low to moderate angle. Sharply overturned beds in the lower plate close to the fault trace indicate that the upper plate overrode the lower from the west (see cross section on pl. 1).

The Allen's Ranch thrust fault is inferred to extend southward beneath the volcanic cover passing between the Independence (Silver Shield) shaft 1¾ miles northeast of Dividend, and Tintic Standard Diamond Drill Hole No. 11, which is 2,000 feet north-northwest of this shaft. According to company maps and information received orally from R. T. Walker, the Independence workings penetrated

strongly distorted and fractured beds of dolomite and sandstone believed to represent the Humbug formation or Great Blue limestone; the diamond drill hole, in contrast, penetrated the Ophir formation, which is assumed to occur on the overriding plate of the fault.

The Chief Oxide fault, which is known from diamond drill holes that cut the sedimentary rocks beneath the Packard quartz latite 7/8 mile east-southeast of Dividend in SE1/4 sec. 15, T. 10 S., R. 2 W., is believed to be a thrust or reverse fault with a stratigraphic displacement comparable to that of the Allen's Ranch thrust fault, and may possibly represent a southward extension of this same thrust fault zone.

Pinyon Peak thrust fault

A thrust fault with somewhat less stratigraphic displacement than the Allen's Ranch thrust fault has been traced northeastward from the southeast base of Pinyon Peak to the area of the North Standard mine, which is located 2 3/4 miles north-northeast of Dividend. A probable continuation of this same fault zone occurs about a mile east of the Allen's Ranch thrust fault close to the edge of bedrock at the extreme southeastern side of Cedar Valley. This fault is locally concealed by lava and colluvium, and is cut and displaced by several transverse strike-slip faults, but is probably related in origin to the Allen's Ranch thrust fault and trends subparallel with it.

The stratigraphic displacement shown by the Pinyon Peak thrust ranges from a few hundred feet or less to more than 1,500 feet; it is greatest near the North Standard shaft where the Middle Cambrian Cole Canyon dolomite overlies the Upper Ordovician Fish Haven dolomite. The fault plane dips gently to the west, and drag folds indicate that the upper plate overrode the lower plate from the west (see cross section on pl. 1).

Tintic Humbolt thrust fault

A thrust or reverse fault zone, whose origin is related to horizontal strike-slip movement along two large northeast-trending faults that cut the overturned strata of the eastern limb of the North Tintic anticline, crops out in the

central part of Gardison Ridge in secs. 12 and 13, T. 9 S., R. 3 W., 6 miles north of Eureka. This fault zone consists of several plates, but in general strikes about N. 40° W. and dips about 35° to the southwest. At the point of maximum displacement, beds near the top of the Upper Ordovician Fish Haven dolomite are thrust over beds near the base of lower member of the Lower Mississippian Madison limestone, indicating a stratigraphic dislacement of about 1,000 feet, and a true displacement measured along the plane of the fault of about 1,800 feet.

Bradley thrust fault

An east-dipping reverse fault, whose origin may be ascribed to thrust faulting, crops out near the Bradley shaft in the NE¼ sec. 2, T. 10 S., R. 3 W., 2¼ miles northwest of Eureka. This fault strikes approximately N. 10° W. and dips to the east at a moderate angle. The stratigraphic displacement shown by the fault is approximately 350 feet, and the true displacement is estimated to be about 600 feet. The upper plate of this minor thrust probably moved relatively to the west in contrast to the relative eastward movement of the upper plates of the other thrust faults.

Tintic Standard thrust fault

A zone of low-angle faults separates the Tintic quartzite from younger formations at depth throughout a substantial part of the East Tintic mining district. This fault has been given the name Tintic Standard fault by Lovering and his associates (1949, p. 14). The plane of this fault has been folded into a curving, northwest-trending asymmetric syncline lying just west of the crest of the East Tintic anticline. This syncline extends from the Tintic Standard mine to the North Lily mine, and its southern part has been cross-folded into an east-northeasterly trending syncline forming the Tintic Standard "pothole," which is described on page 43. The Ophir formation and younger Cambrian rocks above the Tintic quartzite localize a number of smaller thrust faults throughout the East Tintic mining district; some of these faults are crumpled indicating that the general bedding plane thrust movement localized near the quartzite contact took place toward the end of the general period of folding.

Other low-angle faults

Most bedding planes of the folded strata, especially those forming the boundaries of shale units, show clear evidence of movement. In some places this movement is not confined to the bedding planes but follows faults that intersect the beds at a low angle. A fault of this type follows the basal phosphatic shale member of the Deseret limestone a short distance west of the Crown Point No. 3 shaft in the SW¼ sec. 20, T. 10 S., R. 2 W., 2 miles southeast of Eureka, and brecciates and cuts out some of the beds of the upper member of the Madison limestone. Faults of this type are the rule rather than the exception in the steep western limb of the Tintic syncline, and several of them localize major, north-trending zones of replacement ore bodies in the Main Tintic district.

HIGH-ANGLE FAULTS

General statement

The high-angle faults exposed in the East Tintic Mountains are broadly classified into the following groups:

1) Faults formed during folding.
2) Faults formed after folding but before volcanic activity.
3) Post-volcanic, mineralized fault-fissures.
4) Late normal faults.

As may be expected, many faults show evidence of more than one period or type of movement, but these faults are classified according to the period during which the dominant displacement took place.

Owing to the large number and complex relations of the high-angle faults, the following discussion is limited to the general characteristics of each group. For a more complete discussion with descriptions of individual faults the reports of Kildale (1938) and Lindgren and Loughlin (1919) are recommended.

Faults formed during folding

The earliest high-angle faults form a conjugate system of northeast- and northwest-trending shear faults that de-

veloped in response to the east-west compressive forces that produced the folds. The dominant faults of this group are persistent, northeast-trending strike-slip and tear faults, some of which cut entirely through the range, and locally show stratigraphic displacements of several thousand feet. The faults of this system that cut the crest of the North Tintic anticline also show considerable vertical displacement; along each the southeastern block has moved down with respect to the northwestern block, which suggests partial collapse of the anticlinal structure. The strikes of the principal northeast-trending faults range from N. 45° E. to N. 65° E., and the dips are chiefly vertical or steep to the southeast.

The apparent horizontal displacement along some of the northeast-trending strike-slip faults varies both in amount and direction; the variation may be attributed to differences in the intensity of minor folds in adjacent blocks, and to independent movement of individual blocks. The horizontal displacement along other northeast faults is attributed to displacement along thrust faults that are either exposed or occur at considerable depth.

In the Main Tintic and East Tintic mining districts the northeast-trending faults localize large replacement ore bodies near points where they are intersected by north and north-northeast trending fault-fissures.

The more important of the northeast-trending strike-slip faults include: the Topliff, South Essex, Stroud, Gardison Ridge, Tintic Prince, Lehi Tintic, and Paymaster No. 1 faults in the North Tintic mining district; the Paxman, Beck, Centennial, Grand Central, and Mammoth faults in the Tintic district; the Iron King fault, and possibly the Eureka Standard fault, in the East Tintic district; and the Tintic Chief and two other unnamed faults of large displacement in the southern part of the range. Many of these faults are described in detail in the other reports included in this guidebook that deal with the ore deposits of the East Tintic Mountains.

The northwest-trending shear faults, which form the conjugate system with the northeast-trending strike-slip faults, range in strike from N. 45° W. to N. 60° W., and for the most part dip steeply to the southwest. They both offset and are offset by the northeast-trending faults, but in gen-

eral are largely subordinate to them. The principal displacement along the northwest-trending faults is horizontal, but some faults show early reverse movement. Other northwest-trending faults show late normal displacement apparently related to "Basin and Range" faulting. The tendency of the northwest-trending faults to have been tightly closed by strike-slip movement along the notheast-trending faults probably accounts for the absence along them of large and extensive ore bodies, which are more commonly associated with the northeast-trending faults.

Representative northwest-trending faults include: the Miner's Canyon, New Bullion, Red Hill, and Fremont faults of the North Tintic district; the Gemini, California, Bulkhead (Chief No. 1 mine), and Yankee faults of the Tintic district; and the Eureka Lilly and other unnamed faults in the East Tintic district.

Associated with the master northeast-trending strike-slip faults are short west-northwest and east-northeast trending second-order shear faults that intersect the larger faults at acute angles. These second-order shear faults apparently developed as a result of movement along the master faults, but some show later displacement of other types believed to be the result of continued tectonic activity after the original development of the fault. Possible examples of second-order shear faults include: the Leadville fault exposed in the Chief No. 1 mine, the North Carolina and Virginia faults in the Centennial Eureka mine, and other unnamed faults in the North Tintic district.

Faults formed after folding but before volcanic activity

Two east-trending, north-dipping normal faults of large displacement cut the sedimentary rocks in the northern half of the range, but do not cut the Packard quartz latite, which partly overlies them. They either terminate or displace the northeast- and northwest-trending faults, but actual intersections with these faults are exposed in only a few localities. The northern of these two east-trending normal faults is partly concealed by the lava mass underlying Packard Peak; it has been named the Dead Horse fault in the western part of the range, and the Homansville fault in the east-central part of the range. The Dead Horse-Homansville

fault strikes east-northeastward and dips steeply to the north. If no strike-shift component of displacement along the fault plane is assumed, the north block of the Dead Horse segment is down about 1,300 feet, and the north block of the Homansville segment is down about 3,600 feet. This increase in the magnitude of displacement to the east suggests rotational movement along the plane of the fault.

The southern of the two east-trending normal faults, which has been named the Sioux-Ajax fault, cuts the main backbone ridge of the range a mile east of Mammoth. The fault zone consists of several strands, but in general it strikes due east and dips 80°, or more steeply, to the north. Displacement along the Sioux-Ajax fault has dropped the steeply dipping beds of the Tintic syncline in the north block against the more gently dipping beds of the trough of the syncline in the south block, indicating a displacement of about 1,600 feet near Mammoth Peak. The position of the Sioux-Ajax fault in the East Tintic district is not known with any confidence, but the northeast-striking Eureka Standard fault shows about 1,100 feet of normal displacement, and may have originated as a northeast-trending strike-slip fault that later may have carried part of the normal displacement recognized along the Sioux-Ajax fault. The east-northeast striking Teutonic fault, which lies a short distance south of the Eureka Standard fault, shows normal displacement, and may also carry part of the movement recognized along Sioux-Ajax.

The Sioux-Ajax fault localizes ore bodies where it is crossed by north- and northeast-trending mineralized fissures in the Mammoth, Northern Spy and Iron Blossom No. 3 mines, but no ore bodies have as yet been found along the Dead Horse-Homansville fault. The Eureka Sandard fault localizes ore bodies in the Eureka Standard and Apex Standard No. 2 mines.

Post-volcanic, mineralized fault-fissures

The veins that cut the larger intrusive bodies, and the mineralized fissures associated with the replacement ore bodies of the Tintic and East Tintic mining districts, occupy fissures and faults of small displacement. Where they cut homogenous rock such as monzonite, lava, and massive low-

dipping quartzite and limestone, these fissures and faults trend north-northeasterly and dip steeply to the west. Where they cut the steeply dipping sedimentary rocks, as in the Main Tintic district, they follow earlier formed north-trending bedding-plane faults.

In the East Tintic district the north-northeast trending fissure zones have been intruded by monzonite and pebble dikes, and are marked by linear zones of hydrothermally bleached and altered lava. They clearly cut thrust faults and the northeast-trending shear faults, but appear to terminate against the Homansville fault.

The origin of the north-northeast trending fissures is not clearly understood. They probably guided the emplacement of the Silver City monzonite stock and other monzonite stocks satellitic to it, and they cut the lavas and most of the structures observed in the sedimentary rocks. However, they also seem to cut the monzonite and to be cut by the latest movement along the Eureka Lilly fault. These relations suggest that the fissures were originally formed in response to weak tectonic forces, but shortly after formation were further ruptured and enlarged by forces related to the intrusion of the monzonite. Continued tectonic activity may have reactivated some of them, and caused the development of minor faults in the intrusive bodies. Still later movement along the Eureka Lilly fault cut and displaced even the latest formed fissures.

Late normal faults

Late normal faults are locally exposed near the edges of the East Tintic Mountains and suggest that at least part of the general outline of the range is the product of block faulting. One of these faults is exposed in the SW¼ sec. 31, T. 9 S., R. 3 W.; it strikes N. 57° W. and dips west at about 45°. It brings fanglomerate in the hanging wall of the fault against Lower and Upper Mississippian limestone in the footwall; however, it cannot be traced for more than a mile.

A wide zone of late normal faults, with an aggregate displacement of several hundred feet, cuts Ordovician and younger rocks close to the west base of Pinyon Peak. To the north this fault zone, which is named the Selma fault zone

for the Selma mine which explores one of its strands, is aligned with the southeast side of Cedar Valley, and may be the border fault of this segment of the range. Farther north, in the SE¼ sec. 9, T. 9 S., R. 2 W., the north-trending bedrock mass is offset to the east along a northeast-trending fault that shows both strike-slip and normal movement, suggesting that the Selma is displaced along the northwest-trending fault, which appears to extend east beyond the southern tip of the Fox Hills.

To the south the normal displacement along the Selma fault zone is probably distributed along the Eureka Lilly and Centennial faults, and along other faults parallel to the Centennial fault, all of which show some evidence of late normal displacement.

Local brecciation of the sedimentary rocks at the edge of alluvial fill between Riley's Canyon and Jericho Pass in the southeast part of the range suggests the existence of a late normal border fault a short distance west of the edge of the alluvium. The general straightness of this segment of the range is contributory evidence for the existence of a border fault in this area.

No direct evidence is recognized for the existence of a border fault along the northwest and entire eastern margins of the range, but gravimetric data recently presented by Cook and Berg (1955) indicate deep valley fill deposits in these areas, and by inference, the existence of north-trending faults of large displacement near the margin of the bedrock. The moderate east and west dips of the beds of the Salt Lake(?) formation near Boulter Pass further indicates late faulting in this area.

SUMMARY OF GEOLOGIC HISTORY

Proterozoic era:

A. Deposition of medium- to fine-grained clastic sediments of the Big Cottonwood(?) series of Upper Precambrian age.

B. Erosion of Upper Precambrian formations younger than Big Cottonwood(?) series, if any, prior to deposition of the Tintic quartzite of Early Cambrian age.

Paleozoic era:

A. Essentially continuous deposition of dominantly carbonate sediments in broad miogeosynclinal basins during essentially all of the Paleozoic era. Intervals of epeirogenic uplift indicated by several disconformities.

Mesozoic era:

A. Deposition of marine and terrestrial sediments during the Triassic Period and the early and middle parts of the Jurassic Period, as indicated by general pattern of distribution and composition of sedimentary rocks of these ages in the Wasatch Range and the West Hills area of Long Ridge.

B. Orogeny beginning in latest Jurassic or Early Cretaceous time; chiefly regional uplift possibly accompanied by thrust faulting in areas adjacent to the East Tintic Mountains.

C. Orogeny (early Late Cretaceous); development of broad, east-trending flexures.

D. Orogeny (middle to late Montana) resulting in the principal deformation of the Paleozoic rocks of the East Tintic Mountains. During this orogeny the north-trending anticlines and synclines were formed in response to east-west compressive forces, and thrust and shear faults developed as the folds steepened.

E. Cessation of compressive forces; development of east-trending normal faults in response to north-south tensional forces (latest Montana to Paleocene).

Cenozoic era:

A. Inception of pre-volcanic relief of East Tintic Mountains chiefly by uplift along north-trending faults (early Eocene).

B. Volcanic activity, intrusion and mineralization accompanied by normal faulting (late middle Eocene). During this interval the East Tintic area stood as a highland bordered on the east by a

large lake in which the Green River formation was being deposited.

C. Gap in structural history (late Eocene through early Miocene); during this interval the Basin and Range physiographic province developed as a result of block faulting.

D. Intermittent normal faulting near the margins of the present ranges (early and middle Miocene); accumulation of valley-fill deposits.

E. Deposition of terrestrial and lacustrine deposits of Salt Lake(?) formation (middle or late Miocene to middle or late Pliocene).

F. Pedimentation of Salt Lake(?) formation and older valley-fill deposits (late Pliocene).

G. Renewed movement on range-front faults, tilting of mountain and valley blocks, and deposition of fanglomerate (late Pliocene to early Pleistocene).

H. Dissection of pediments (early to middle Pleistocene).

I. Deposition of Lake Bonneville sediments (Wisconsin).

J. Erosion with deposition of clastic sediments of the modern cycle.

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ORE DEPOSITS OF THE MAIN TINTIC MINING DISTRICT

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INTRODUCTION

The gross value of metal produced from the Main Tintic district is estimated at $315,000,000 from approximately 12,100,000 tons of ore. These figures, based on data from the U. S. Bureau of Mines and U. S. Geological Survey Professional Paper 107, are incomplete, with the true figures probably substantially higher.

The following percentages are computed from the total gross metal values of the district: silver accounts for 43.5 percent, lead for 28.5 percent, gold for 16.0 percent, copper for 10.0 percent and zinc for 2.0 percent. However, if the smelter schedules of 1957 are used to compute the net smelter return from this production, the following relative importance of the metals is obtained: silver accounts for 55.0 percent of the total value, lead for 18.0 percent, gold for 20.0 percent, copper for 5.0 percent and zinc for 2.0 percent. It is thus evident that silver and gold are of greatest importance if the net smelter values are considered rather than gross metal values.

The first ore discovery in the East Tintic Mountains was made in 1869 on croppings of the mineralized fissure veins that cut the Silver City monzonite stock. Outcrops of limestone replacement ores were found soon after near the Mammoth and Eureka Hill mines. Development work from these discoveries resulted, between 1880 and 1910, in the extraction of ores from the south and central portions of both the Gemini and Chief ore zones. The first successful attempt to find concealed ore was made by John Beck who sank an exploration shaft in the bottom of Eureka Gulch and discovered large and rich ore bodies on the northern continuation of the Gemini ore zone. In 1905 two new ore zones, the Iron Blossom and Godiva, were discovered by Jessie Knight, and although they were only a few hundred

feet below the surface for the greater part of their length, no ore cropped out. These discoveries resulted in greatly increased production from the district during the early 1900's. The third important discovery of concealed ore in the Main Tintic district was made by Walter Fitch and J. R. Finlay in 1910. Fitch sank an exploration shaft through the rhyolite in Eureka Gulch and at 1400 feet below the surface discovered large ore bodies at the northern extension of the Chief ore zone. The Chief No. 1 mine has been in continuous operation in this area until very recently and has resulted in the largest tonnage of ore from any mine in the district (3,500,000 tons).

Since the discovery of the Chief mine in 1910, no important new ore centers have been found, although numerous large exploration attempts have been made. At the present time, except for the Dragon mine producing halloysite clay, and the Garity quarry producing silica, there is little mining in the district. Numerous lessees are active in the Bullion Beck mine of the Gemini ore zone and also in the Iron Blossom and Godiva ore zones, but this amounts to little more than scavenging operations.

The writer wishes to acknowledge the use of numerous publications in the preparation of this paper; the more important papers are by Billingsley and Crane 1933, Butler and Loughlin 1920, Kildale 1936, Lindgren and Loughlin 1919, Prescott 1926, and Tower and Smith 1895. The complete list may be found in the bibliography at the end of this paper. Hal Morris of the United States Geological Survey and Max Evans, formerly geologist for the Chief Consolidated Mining Company, have provided much additional information.

The writer also wishes to acknowldge the assistance of Stanley E. Jerome for suggestions and for the proofreading of the manuscript, and the assistance of Harry Pitts who has drafted the illustrations. The assistance of the Rocky Mountain District Staff of Bear Creek Mining Company is gratefully acknowledged. Permission to publish the paper has generously been granted by the management of this Company.

GENERAL GEOLOGY

The major structural element in the Main Tintic district is a broad, north-trending, asymmetric syncline plunging gently to the north with its axial plane dipping to the west at about 55°. The East Tintic district, located three miles to the east of the Main Tintic district, is situated on a complementary anticlinal structure known as the East Tintic anticline. Both the Tintic syncline and the East Tintic anticline are modified by faulting, particularly northeast faults. Other important types of faults include northwest-trending strike-slip faults; east-trending normal faults; and north-trending bedding plane, normal, and thrust faults. Thrusting is especially important in the East Tintic district and would probably be more noticeable in the Main Tintic district if the base of the carbonate section in the syncline could be examined.

The folding and the major part of the faulting are believed to have occurred in Late Cretaceous time. During Middle Eocene time, rhyolitic, latitic, and andesitic lavas were extruded upon a surface of considerable relief. These flows probably covered most of the Tintic Mountains. Igneous rocks of monzonitic and quartz monzonitic composition later intruded the sediments and lavas. The largest of these intrusives is the Silver City stock, cropping out over an area of about two square miles at the south end of the Main Tintic district. A group of much smaller stocks extends northeastward from the Silver City stock into the Main Tintic district (see Plate 3). During and after the emplacement of the intrusives, there was considerable hydrothermal activity culminating in the deposition of ore minerals. Locally, post-volcanic faulting, believed to be of the Basin and Range type, has occurred. Such faults are known to bound the East Tintic Mountains on the west.

ORE DEPOSITS

General Statement

The earliest production came from outcropping fissure veins; later, outcroppings of the limestone replacement ore were discovered, and exploitation of these led to the famous "ore runs" of the Main Tintic district. Most of the ore, on

a basis of tonnage and value, has been mined from limestone replacement deposits within the Tintic syncline. The remainder of the production has been derived from fissure veins, in and adjacent to the Silver City stock.

Ores of the Tintic mining districts show a broad spatial and temporal relationship to Eocene intrusives of the East Tintic Mountains. A similar relationship is shown by the ores of the West Mountain (Bingham) mining district to the Bingham (Copper) stock also of Eocene age. The ores of Park City are similarly related to intrusives. It is postulated that a zone of intrusives extends from the central part of the East Tintic Mountains southwesterly to the southern end of the West Tintic and Sheeprock Mountains. Similarly trending zones of intrusives have been noted in the Oquirrh Range and in the San Francisco Mountains. A zone of southwesterly-trending intrusives with associated magnetite deposits is present near Cedar City. B. S. Butler has discussed these associations in numerous publications. The repetition of southwesterly-trending intrusive zones in western Utah, across the grain of the Paleozoic rocks infers a deep control not well reflected at surface. The understanding and interpretation of these relationships is believed to be important in searching for extensions of mining districts and for the discovery of new ore.

Fissure Veins

Fissures are defined here as openings, fractures or sheetings in rocks which are more or less continuous and consistent in trend. Fissure veins are tabular bodies of ore which occupy a fissure or parts of it.

A total gross production of $12,000,000 has been estimated from these ores, although data are scarce and unreliable, and possibly much production credited to the south end of the Iron Blossom and Godiva ore zones properly belongs to the fissures in that area. The most important metal produced is silver, but high-grade ore shoots of lead, gold and copper have also been encountered.

The fissures traverse all rock types in the district, strike predominantly northeast, dip steeply to the west, and often have a small displacement. They occur abundantly at the south end of the Main Tintic district and also

throughout the East Tintic district. Their continuity infers a deep structural control, and it seems more than a coincidence that fissure veins of the Bingham and Park City districts also have the same trend.

Economic mineralization in the fissures constitutes only a small portion of their total length. The ore bodies have an average width of only two feet. In quartzite, extrusive rocks and intrusive rocks, the ore is confined to walls of the fissures whereas in a limestone host rock it extends into the walls for a short distance. In most cases the ores have been enriched by secondary processes and it is unusual to find primary ore rich enough to work below the water table. In the south end of the Main Tintic district the water table ranges from 200 to 700 feet below surface. The fissure vein mines are usually shallow, but the Swansea mine, on one of the largest fissures, is exceptional in having workings well below the water table to depths exceeding 900 feet.

Wall rocks adjacent to the fissures are commonly sericitized, pyritized, and silicified. The surface traces of the fissure veins are often determinable by prominent jasperoid croppings and limonite staining.

Many of the fissures shown on Plate 3 are not individually as continuous as shown on the map; they are simplified and generalized to represent closely associated, braided and en echelon systems. A brief description of the more important zones is presented below.

Beginning on the southwestern side of the Main Tintic district is the Swansea group; unlike the veins further to the east these fissures have a northerly strike and no replacement ore has been found at their northerly extensions into the sedimentary rocks.

Further east is the Yankee Girl-Cleveland fissure system which can be projected north to the Blackjack, Ajax and Gold Chain fissures. These in turn extend north to the vicinity of the Mammoth pipe, a limestone replacement ore shoot that represents the most southerly part of the Chief ore zone. Similarly the Elmer Ray - Sunbeam - North Star - Red Rose - Carisa system extends northward to the limestone replacement ores of the Godiva ore zone. The Triumph - Martha Washington - Dragon and Governor fissure

system, likewise extends to the limestone replacement ore bodies of the Iron Blossom ore zone. This rather abrupt transition from fissure vein to limestone replacement ore takes place where the fissures cross the Sioux - Ajax fault. This fault is of the normal type, dips steeply to the north and has a displacement of approximately 1600 feet. On the south side of the fault are relatively thin, gently dipping metamorphosed carbonate rocks, whereas to the north they are much thicker, steeply dipping and unmetamorphosed. The fissure veins on the south side of the fault have northeast strikes, and are characterized by copper, silver and gold ores. In contrast, the limestone replacement ores on the north side have a general northerly trend and typically carry lead, silver and zinc. A probable explanation for the changes in the form of the ore, strike and mineralogy is country rock environment. Fissure veins occur in all rock types of the Main Tintic district but there is a tendency for them to change to limestone replacement ore when the host is a thick, unmetamorphosed carbonate rock. The change in strike of the limestone replacement ores is explained by the control exerted by bedding planes and bedding plane faults of the carbonate rocks. The reasons for the differences in mineralogy are more difficult to explain but possibly are due to differences in reactivity between the ore fluids and the carbonate and non-carbonate rocks.

Further east in the southeast corner of the Main Tintic district (see Plate 3) is a wide band of northeasterly-trending fissure veins including the Treasure Hill - Little May - Alaska, Niebauer - Tesora - New State, Laclede - Homestake and Showers - Bowers. The map suggests these die out to the northeast, but, the writer agrees with Hal Morris of the Geological Survey (personal communication) that many of the fissures in the East Tintic district may be on the projection of this group. This intermediate area, apparently devoid of fissure veins, is occupied by a thick pile of volcanic rocks in which the continuity of mineraliaztion was not maintained. A great zone of hydrothermal alteration and silicification occurring in this area may reflect the leakage of hydrothermal fluids from this projected northeasterly zone of fissure veins.

Numerous mines and prospects southwest of the Showers - Bowers fissure suggests a possible extension of this fis-

sure vein three miles beyond the southern limit of Plate 3. If these fissure veins actually do extend into the East Tintic district, their total known length would be nine miles, a figure which emphasizes the persistency of these structures.

Limestone Replacement Ore Bodies

Most of the ore produced from the Main Tintic district has come from limestone replacement ore bodies. An examination of Plates 3 and 4 shows that these deposits are situated at the north end of the district, occur in definite linear zones and are on the northern projection of many of the prominent fissure vein systems.

The term "ore zone" is used here although they are called ore runs in the Main Tintic district. They resemble in form and mineralogy the "mantos and chimneys" of the Mexican silver - lead province and especially the Santa Eulalia orebodies in the State of Chihuahua, Mexico. In certain respects they also resemble the limestone replacement ore bodies of Gilman, Colorado.

The four principal ore zones named from west to east are the Gemini, Chief, Godiva, and Iron Blossom. The Plutus, located between the Chief and Godiva, although of smaller magnitude, is of the same general type. The ore zones strike north, are parallel or subparallel to the bedding, and have a gentle plunge to the north similar to that of the synclinal axis. Commonly the ore zones have one long dimension and two short ones; they often contain individual ore bodies or ore shoots, sometimes side by side and sometimes one vertically above another. These shoots may be interconnected, as in the Godiva and Iron Blossom zones, or they may be isolated, as in parts of the Chief and Gemini zones. Although the general strike and plunge of the ore zones can be predicted with some degree of certainty, much development and exploratory work is necessary to find the ore shoots within the zones. This explains the repeated attempts of the mining companies and lessees to explore for individual ore shoots that might have been missed when the zone was being mined.

In many cases the ore zones show considerable modification by northeast faulting and, to a lesser extent, by northwest faulting. At intersections with faults they often

enlarge in plan and section and form vertical chimneys or very rich horizontal concentrations of ore. It is safe to state that the major profits of the mines have been derived from such areas. Such ore bodies as the Granite pipe and 18-316 ore body of the Chief Consolidated mine, the Billings pipe of the Gemini mine, the California and Virginia pipes of the Centennial Eureka mine and the Mammoth pipe of the Mammoth mine have accounted for the bulk of the profits from these properties.

The persistence of the ore zones across faults and through different stratigraphic units is a very striking feature. Because of the distribution of the ore zones in the syncline and also because of the extensive faulting, ore is found through a range of 6,000 feet in a great number of formations from Cambrian to Mississippian in age (see Figure 6).

The ore zones are surprisingly continuous in their strike, persisting for distances of 8,000 to 9,500 feet. Only the Chief ore zone has been intensively mined below the water table, although recently this operation was discontinued. The failure to explore the Chief ore zone down dip and to follow the Gemini ore zone beneath the water table was entirely the result of adverse economic factors rather than exhaustion of ore. We now have reason to believe that the Gemini and Chief ore zones continue to the north, and we believe that the Godiva and Iron Blossom ore zones also continue in a northerly direction.

The habits of each ore zone differ and for this reason a brief description will be given of each.

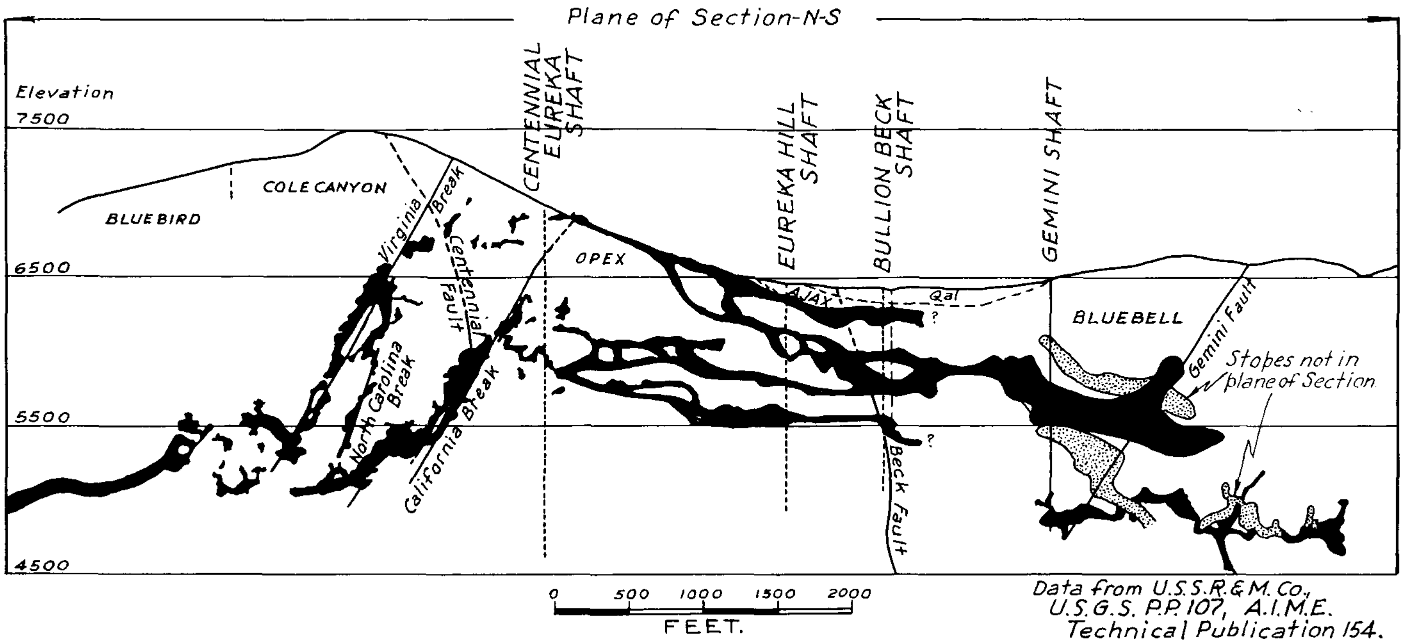
Gemini Ore Zone: This ore zone (see longitudinal section, Figure 7) extends from the Grand Central mine to the Gemini mine, a total distance of 8,000 feet. Production is estimated to exceed $97,000,000, half of which has come from the Centennial Eureka mine. An examination of Plate 3 shows the pronounced zoning from copper to lead in following the ore from south to north.

At the south end of the zone the ore occurs chiefly in the Ajax formation and is localized by the intersection of favorable beds and northerly and notheasterly trending fissures. Near the Grand Central mine the ore zone is horizontal,

AGE	UNIT	THICKNESS	Approximate Gross PRODUCTION
		Feet	(Dollars)
Middle or Upper Eocene (Intrusive)	Silver City Monzonite		12,000,000.
	Swansea Quartz Monzonite		
Middle Eocene (Extrusive)	Laguna Latite Series		
	Packard Rhyolite Series		
Mississippian	Humbug	650	
	Deseret	875	46,500,000.
	Madison upper member	500	43,000,000.
	Madison lower member	250	
Miss-Dev.	Piñon Peak	160	
Devonian	Victoria	350	
Dev.-Sil.	Bluebell	500	110,000,000.
Ordovician	Fish Haven	280	10,000,000.
	Opohonga	875	9,000,000.
U. Cambrian	Ajax	640	60,500,000.
	Opex	500	7,500,000.
	Cole Canyon	600	7,000,000.
	Blue Bird	180	10,000,000.
M. Cambrian	Herkimer	375	
	Dagmar	90	
	Teutonic	390	
M-L. Cambrian	Ophir	440	84,500,000.
L. Cambrian	Tintic	3,000	25,000,000.
8,155 Feet			

TOTAL GROSS PRODUCTION~425,000,000.

FIGURE 6. Distribution of the total production of the Main and East Tintic mining districts from various rock units.



GENERALIZED SECTION OF THE GEMINI ORE ZONE

FIGURE 7

but in the vicinity of the Centennial fault the principal ore bodies occur as steeply inclined chimneys. These chimneys account for the bulk of the production from the Centennial Eureka mine and are localized where the ore zone intersects a series of south dipping, east-striking crossbreaks. North from the Centennial Eureka mine and through the Eureka Hill mine, the ore zone is composed of a series of separate lenticular ore shoots lying along steep bedding planes in the Ajax formation. At the Beck fault, the ore zone forms another irregular vertical chimney of ore which passes from the Ajax formation south of the fault to the Bluebell formation north of the fault. The difference in lithology does not appear to affect the character of the ore in any respect. The Gemini mine is located on the most northerly part of the known limits of the ore zone and the ore shoots are similar to those in the Eureka Hill and Bullion Beck mines, being characterized by great irregularity and discontinuity. However, the ore zone itself is well-defined in these mines, is parallel to the bedding and plunges gently to the north. The last known ore in the Gemini mine is 2,400 feet lower in elevation than the outcrop of the ore zone a short distance south of the Eureka Hill shaft. The available information suggests that only economic factors (e. g. costs of mining below the water table) prevented the development of the ore farther to the north.

Except for a minor amount of leasing in the Bullion Beck mine, very little exploration or mining activity is being carried out along this ore zone (1957).

Chief Ore Zone: This ore zone (see longitudinal section, Plate 8) extends from the Mammoth mine to the Chief Consolidated mine, a total distance of 9,500 feet. Production is estimated to exceed $140,000,000 over half of which has come from the Chief Consolidated mine. It is interesting to note that at prices prevailing in 1957 this production would be valued at approximately $250,000,000. From south to north the ore shows a zoning of copper - gold - lead - silver, to lead - silver and finally to lead - silver - zinc.

The Chief ore zone begins at the impressive Mammoth ore pipe, a nearly vertical chimney 2,400 feet in vertical extent containing shoots of copper, gold, lead, and silver ores. Mining of this pipe was stopped at the water table,

but it is reported that mineralization continues below this level. Unfortunately, the geology and ore controls of this great ore chimney have not been worked out in detail, but it is probable that the intersection of mineralized north-northeasterly - trending fissures and the eastward striking Sioux - Ajax fault zone is to a large extent responsible for the localization of this orebody and the associated brecciation.

From the area of the Mammoth pipe and the Mammoth fault, the ore zone plunges seeply northward along favorable beds to the Grand Central mine where the run flattens out and is localized in the steeply eastward dipping beds of the Bluebell formation. Proceedings north again along the zone, the ore shoots become increasingly complex through the Eagle and Bluebell mines and into the Chief Consolidated mine. The most striking feature of this part of the ore zone is the modification and enlargement of the ore in plan and section at its intersection with numerous cross-faults, especially those with a northeasterly trend. Within the boundary of the Chief Consolidated mine the ore zone continues persistently northward until it reaches the Beck fault where it expands and follows this fault to the northeast for 2,000 feet. Then it turns and again follows a northerly course. To date the zone has been followed about 600 feet north of the Beck fault where mining has been discontinued because of high pumping costs and the lack of development work.

In longitudinal section, the northern half of the Chief ore zone has an overall northward plunge of about 21°, roughly parallel to the plunge of the Tintic syncline. At the intersections with cross - faults (for example the 1050 fault, the Centennial fault, the Intermediate fault) steeply inclined ore chimneys are developed. The ore zone had been mined to the 2800 level at its most northerly extension and was partially developed on the 2900 level when operations were suspended in 1955 because of economic factors.

Within the Chief Consolidated mine there has been a pronounced decrease in silver and an increase in the zinc content of the ore in depth. Most of the ore above the water table is oxidized to some extent, and this may explain the high silver content in the upper part of the mine.

The last development work on its northerly extension indicates that the ore probably continues its downward plunge in the Bluebell formation.

The management of the Chief mine recently suspended all operations and at present there is very little mining activity on this ore zone.

Godiva Ore Zone: This ore zone extends from the Sioux-Ajax fault to the Godiva mine, a total distance of slightly over 8,000 feet. Production figures are very scanty, but the value of ores produced is estimated to exceed $20,000,000.

This ore zone has its beginning in the extension of a well-defined system of northeasterly-trending mineralized fissures, described previously. From the Sioux-Ajax fault the ore zone extends almost due north, is generally horizontal and follows a coarse-grained limestone bed in the Deseret formation. The Deseret limestone along this ore zone is on the west limb of the Tintic syncline near the synclinal axis and dips between 30 and 60 degrees to the east. Unlike the Gemini and Chief ore zones, the Godiva ranges through only a small vertical interval, generally between 7,000 and 7,300 feet in elevation. Although the ore never crops out, it comes within 60 feet of surface in one place (low-grade jasperoid does crop out in the Little Spy and Humbug mines). North of the Godiva mine it plunges to the north, and Kildale (1936) reports that the ore becomes more siliceous and increases in zinc.

Little mining or exploration work is being done on any part of the Godiva ore zone; however, a small amount of leasing is going on in the Spy, Salvador and Mountain View mines.

Iron Blossom Ore Zone: This ore zone (see longitudinal section, Plate 6) extends from the Iron Blossom No. 3 mine to the Beck Tunnel No. 2 shaft, a total distance of approximately 5,200 feet; however, if the fissure vein system of the Iron Blossom No. 1, Governor, Martha Washington and Triumph are included, a total length of 15,000 feet is obtained (see Plate 3). Production is estimated to exceed $36,000,000. Because of the ease of mining and the high silver values, profits were unusually high; probably in the order of 33 percent of the gross.

This ore zone is similar to the Godiva, in that it is on the northern extension of a well-defined system of mineralized fissures. These fissures upon reaching the Sioux - Ajax fault die out and are aligned with north-trending replacement ore bodies. North of the Sioux-Ajax fault the ore zone can be traced for 5,200 feet and at its northern end turns northwesterly and joins the Godiva. The Iron Blossom ore in the Deseret formation is approximately along the axis of the Tintic syncline. The zone is unique in that it consists of a horizontal pipe of ore 5,000 feet in length with a width of 20 to 170 feet and a height of 20 to 60 feet. Near the Sioux - Ajax fault the controls for this zone appear to be the intersection of steep fissuring with a flat, coarse - grained limestone bed along the axis of the syncline. In the northern part of the Beck Tunnel property the horizontal ore swings northwesterly out of the synclinal axis. The zone then joins the Godiva zone south of the May Day mine and individual ore shoots become more irregular and less continuous.

A moderate amount of leasing is being done (1957) in the Iron Blossom No. 1, Iron Blossom No. 3, and Colorado No. 1 mines. In the main, however, the work appears to be scavenging operations.

Mineralogical Characteristics of the Ores

The principal metals of the fissure ores are copper, silver and gold, with minor amounts of lead and zinc. Important primary minerals of the fissure ores are enargite, silver sulfides and galena. Minor amounts of sphalerite, chalcopyrite, arsenopyrite and tetrahedrite also are present. The gangue minerals most commonly are pyrite, quartz, calcite and barite.

The principal metals of the limestone replacement ores are silver and lead with lesser amounts of gold, copper and zinc. In some mines, such as the Centennial Eureka and the Mammoth, copper and gold account for the major part of the production. The more important primary minerals of the limestone replacement ores are galena, sphalerite, argentite, enargite and tetrahedrite.

The sulfide ore tends to be vuggy and crustiform while the oxide ore, from which the bulk of the production of the district has been obtained is crumbly, cellular and iron

stained with an overall density lower than that of the host rock. The zone of oxidation is deep, ranging down to 2000 feet below the surface at the north end of the Main Tintic district. The larger ore bodies are seldom completely oxidized and some sulfides are often found high above the water table, especially where they have been protected from oxidation by fault gouge or shales. The more common oxidized ore minerals include malachite, azurite, chrysocolla, covellite, anglesite, cerussite, smithsonite, calamine, hydrozincite, cerargyrite, native silver and plumbojarosite as well as a host of rarer minerals. Noncommercial minerals associated with the oxidized ores include kaolin, alunite, gypsum, limonite and the manganese oxides.

Metal and Mineral Zoning

A broad zonal arrangement of metals is suggested in the Main Tintic district with dominantly copper-gold giving way northward to silver-lead ores and finally to lead-zinc ores. The exact interpretation of this zoning is made difficult by the differences in mineralogy between fissure ore and bedding ore, and by the differences in mineralogy between ores of the vertical chimneys and the horizontal shoots in the same locality.

The following facts seem to be well established:

1. Copper - barite - gold is a characteristic assemblage of the fissure vein type of mineralization even where bedding replacement ores are in juxtaposition.
2. Lead - silver - zinc is a characteristic assemblage of the bedding replacement ores. Zinc increases in both the Chief and Godiva ore zones where they plunge steeply north at their northerly extensions.
3. The chimneys or pipes associated with the ore zones are higher in lead, zinc and silver than the average ore from the zone and contain considerably more gold and copper. In many of the chimneys, however, gold - copper and lead - silver ore shoots have been found side by side, and in the Mammoth pipe rich copper ore bodies were found to overlie those rich in lead and silver.
4. An examination of Plate 3 shows a definite increase in copper at the south end of both the Gemini and

Chief ore zones. However, this apparent horizontal zoning might be due to the chimneys at the southern end of these zones.

Hydrothermal Alteration

Unfortunately hydrothermal alteration in the Main Tintic district has not been so intensively studied as in the East Tintic district. Nevertheless there are abundant indications of alteration, some types of which are closely related to ore.

At the south end of the Main district the igneous rocks commonly are highly altered, especially adjacent to mineralized fissures. Pyritization, silicification, baritization and sericitization are characteristic types of alteration near the fissures and a propylitic suite of minerals including sericite, chlorite, epidote, calcite, opal and pyrite occurs further away. In some localities such as Ruby Hollow, Diamond Hollow and Treasure Hill, large areas have been intensely altered. In general a broad northeast-trending band of alteration can be traced from the fissure veins at the south end of the Main Tintic district to the East Tintic district.

The Dragon halloysite deposits have resulted from the hydrothermal alteration of a large septum of limestone at the northern margin of the Silver City stock. The clay and associated hematite and limonite are ascribed to hydrothermal effects rather than the contact metamorphism that extends into the carbonate rocks for an average distance of 1000 feet from the stock. Lovering and his associates (1949, p. 25) point out that in the East Tintic district there is a clear relation of argillized lava to centers of intrusive activity. Another large area of intense argillization of sediments is in the vicinity of the Raddatz clay pits, a short distance northwest of Packard Peak. Here the argillization appears confined to the base of the volcanics and unlike the Dragon occurrence no intrusives are exposed at the surface. At the present time no commercial use has been found for the clay occurring at the Raddatz locality.

Near the ore zones of the Main district hydrothermal alteration is not so conspicuous as that near fissure vein deposits. Hydrothermal dolomitization, although not studied in detail, appears to extend for great distances, and has

a district relationship to the mineralized areas rather than to individual ore bodies. North and east of the Main district, where the carbonate rocks are covered by rhyolite and latite, the base of the volcanic rocks are commonly chloritized. The chloritization, no doubt, resulted from altering fluids similar to those that dolomtized the carbonate rocks (Billingsley, private report and Lovering, 1949, p. 21).

North of Eureka and in the vicinity of Packard Peak a considerable volume of volcanic and carbonate rocks has been hydrothermally altered. Jasperoidization (silicification) and argillization of the sedimentary rocks here, immediately below the volcanic series, suggests the impounding of upward-migrating, silica-rich hydrothermal fluids. The pyritic and argillic alteration of the volcanics directly north of Eureka, expressed at the surface by staining and bleaching, has been ascribed to the leakage of hydrothermal fluids related to the ore bodies of the Chief ore zone in Eureka Gulch. Very few subsurface data are available to substantiate this idea other than a large volume of brecciated jasperoid found at a considerable depth below surface in the 1A drill hole and in the 1800 drift of the Longyear Company.

The limestone relacement ore shoots are generally cased with jasperoid ranging from a few feet to several tens of feet thick; the jasperoid itself is often weakly mineralized with silver, lead, zinc, and less frequently with gold. Much of this has been mined in the past as low grade siliceous ore for smelting flux. The siliceous casing, however, acts a good support in the stopes and its removal has often produced roof problems. The jasperoid is frequently surrounded by porous granular dolomite, sometimes referred to as "chocolate rock." This material is believed to have formed from the leaching of pyrite disseminated through the hydrothermally dolomitized rock (see paper by Howd in this guidebook titled *Hydrothermal alteration in the East Tintic mining district*).

Ore Controls

Fissure Veins: The ore controls are relatively simple as compared with those of the limestone replacement ores. Orebodies or ore shoots of the fissures are limited by the strike and dip of the openings and are generally confined to them,

although in the case of carbonate host rocks the ore does have a tendency to work into the walls. As to why a particular part of a fissure should contain ore while another part is barren is difficult to answer, but the reason is probably related to the physical nature of the openings in the rock, both at the time the ore fluids were active, and when secondary enrichment took place. The fact that very few of the fissures ore bodies were worked below the water table emphasizes the importance of oxidation to ore formation. The sharp transition of fissure ore to typical limestone replacement ore, referred to previously, indicates that the importance of fissures as ore controls diminishes very abruptly as they pass from igneous rock or quartzite into unmetamorphosed carbonate rocks. The relative volume of ore in the different rocks indicates the inhospitability of the igneous rocks and the favorability of the highly reactive carbonate rocks.

Limestone Replacement Ores: The question of ore controls for the limestone replacement ore, as would be expected in a district of this type, has been a matter of debate since ore was first discovered. In a highly reactive rock many subtle factors are responsible for the deposition of ore and it usually is difficult to recognize them all.

From the broad point of view, the ore zones are closely related to the regional orientation of the Tintic syncline. The zones tend to follow the strike of the bedding and in general, parallel the plunge of the fold.

The ore usually is restricted to favorable carbonate formations such as beds in the Ajax, Pinon Peak, Bluebell and Deseret (see Figure 6). The important ore beds are characteristically interbedded with shale. This is of great importance, for under tectonic stress the shale flowed and the competent limestone fractured. The shales served as inert, locally impermeable barriers to the ore fluids which deposited their load in the reactive limestone.

Fault control is also very important, especially at the north ends of the Chief and Gemini ore zones where vertical and horizontal enlargements and improvements in values take place where strong faults break across the ore zones.

The importance of fissures in controlling the ore zones is difficult to assess. The writer believes that apart from

serving locally as feeders the fissures exerted relatively little influence on either the orientation or the shape of the ore bodies. An exception to the above statement is in the situation where a fissure vein leads into a bedding plane fault; here the fault is the important control while the fissure served as a feeder to it.

Large drag folds, probably formed in conjunction with the northeast faulting, are important ore bearing structures in the Chief mine.

Origin of the Ores

As with the problem of ore controls the problem of origin has been debated for many years. The three major hypotheses on origin of the ores are presented briefly:

1. The ore fluids originated in the Silver City stock as products of differentiation. Lindgren and Loughlin appear to be the chief proponents of this hypothesis which they justify by the spatial and mineralogical relationships of the ore to the intrusive stock.
2. The ore fluids originated to the north, probably in the vicinity of Packard Peak. This might explain the increase in zinc over lead at the northern end of the Godiva and Chief ore zones. The main argument in favor of this hypothesis is the overall plunge of the ore zones to the north. Work thus far undertaken on quartz overgrowths indicates that in and north of the Chief No. 1 mine the fluids depositing silica moved up dip and to the south.
3. The ore originated from multiple centers within the district This theory is supported by Billingsley and Kildale. A complete discussion of this hypothesis is given in Kildale's thesis and in Billingsley's paper written for the 16th International Geological Congress meeting. The discovery of apparently isolated ore bodies (in the East Tintic district) led to the development of this view and lends support to it. Kildale envisages at least ten, and probably twelve principal centers of mineralization, while Billingsley indicates seven.

It is the writer's opinion that the latter explanation is the more plausible of the three presented, and he would stress the probable importance of the northeast fissures as deeply penetrating structures responsible for "tapping" the ore fluids. The close temporal and spatial association of the monzonite intrusives, pebble dikes, hydrothermal alteration and metallization suggests a common origin. It is significant, too, that all these features are to some extent controlled and modified by northeasterly-trending fissures.

Exploration

Although the material for this section has come from many sources, the most important contributors have been Max Evans, formerly geologist for the Chief Consolidated Mining Company and Hal Morris of the Geological Survey.

Only a few of the more interesting and important exploration attempts and discoveries are discussed. One of the earliest discoveries of concealed ores was made by John Beck who sank a shaft in the bottom of Eureka Gulch on the northern projection of the Eureka Hill ore bodies. As a consequence of this work the prolific Bullion Beck ore body was discovered and resulted in the development of the northern end of the Gemini ore zone.

Another important success, achieved by Jesse Knight, was the discovery of the Iron Blossom and Godiva ore zones. In 1881 he began a tunnel on the northeasterly slope of Godiva Mountain, in an area of highly altered Deseret limestone. At 450 feet he encountered the great Humbug ore shoot, one of the richest lead-silver deposits in the district. Other mines subsequently developing extensions of this discovery were the Uncle Sam, Colorado, Sioux, and the Iron Blossom mines. These are interconnected along an ore channel whose strike length exceeds 1¼ miles. Total gross production from these mines exceeded $36,000,000 with profits of $11,500,000. The Tintic drain tunnel, with the purpose of draining water from the area around Silver City and Diamond, was another Jesse Knight exploration project. The object was to make it possible to mine veins in the intrusive stock at the south end of the district. The project was not completed.

In 1909 Walter Fitch sank a shaft in Eureka Gulch to explore beneath the rhyolite for the northward continuation of the Mammoth-Eagle and Blue Bell ore channels. After an expenditure of $300,000 in sinking and drifting, a silver-lead ore channel was found on the 1400 level in the Chief No. 1 mine. Since then the Chief has been in almost continuous operation. Total gross value of ores produced approximates $75,000,000, with a profit of $7,000,000.

About 1920 E. J. Raddatz, who was responsible a few years earlier for the discovery of the Tintic Standard ore body in the East Tintic district, sank a 1600-foot shaft a few miles north of the Main district. Exploration from this shaft, known as the North Beck, failed to discover ore in Lower Cambrian formations including the middle Ophir limestone.

In 1940, E. J. Longyear Company, Calumet and Hecla, Inc., and Kennecott Copper Corporation joined in a venture to seek lead-silver replacement ore bodies southwest of the Silver City stock. The venture was based on the concept of Emmons and Butler that ore deposits are concentrated along the extremities of the long axes of elliptical stocks and on the idea that carbonate sediments existed below the volcanics at a reasonable exploration depth. The project failed because of deep alluvium to the southwest of the Silver City stock and deep volcanics to the south. No sediments were penetrated by drilling and no ore was found in the volcanics or monzonite.

Between 1945 and 1950 the E. J. Longyear Company undertook extensive geologic studies in the Main Tintic district and subsequently drilled a 2700-foot hole a mile northeast of the Chief No. 1 shaft. Weak mineralization in jasperoid breccia was found near the elevation of the Chief No. 1 mine 1800 level. The jasperoid was then explored by 2100 feet of drifting from the Chief 1800 level and some surface drilling. Unfortunately no ore was found.

In 1947, International Smelting and Refining Company obtained a lease from the Chief Consolidated Mining Company and attempted to explore the northern projection of the Godiva and Iron Blossom ore zones. After considerable drifting and the production of a small quantity of ore, the project was terminated.

The Chief Consolidated Mining Company, between 1947 and 1949, explored the Beck fault and its intersection with the California break (productive in the Centennial Eureka mine), the Ophir formation, and the Emerald dolomite member of the Ajax formation, by sinking the Evans shaft, drifting and subsurface diamond drilling. The project did not discover any ore.

In 1952 the E. J. Longyear Company assembled for exploration purposes a large tract of ground north of Eureka, including properties of large mining companies as well as those of individuals. A unit agreement, fairly unique in the mining industry although common in the petroleum industry, was prepared. After a limited amount of geologic and geophysical work by the Longyear Company, Bear Creek Mining Company took the project over in 1955. Bear Creek mapped the area of the tract in detail, undertook geophysical and geochemical surveys, and diamond drilled selected areas from the surface. These attempts to discover a new ore center were unsuccessful and Bear Creek dropped the project.

It is a striking fact that no successes have attended recent exploration for concealed ores in the Main Tintic district, although considered on a long-term basis, exploration has been successful. The successful ventures described above have resulted in the production of ores having a gross value of approximately $120,000,000 with profits in the range of $25,000,000 to $30,000,000. Total exploration costs are very difficult to determine but probably approximate $2,000,000. This figure takes into account only the projects described here and ignores numerous other minor exploration efforts.

FUTURE OF THE DISTRICT

The future of the Main Tintic district depends upon systematic exploration of favorable areas using all of the available geologic, geochemical and geophysical techniques. Exploration will be costly; it is likely that the present price of base metals will have to improve before there is sufficient incentive for the needed investment.

Aggressive exploration based on sound geologic principles has shown that important concealed ore bodies are

present in the East Tintic district. No geologic reason is evident why new concealed centers of mineralization should not exist in the Main Tintic district. The northern development of some of the ore zones was curtailed because of economic factors; it is conceivable therefore that given more favorable conditions these zones can be followed to greater depths.

The possibilities of non-metallic products such as halloysite and silica which have recently been successfully developed should not be overlooked.

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ORE DEPOSITS OF THE CHIEF MINE

By

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INTRODUCTION

The Chief is the principal producing mine of the Chief Consolidated Mining Company, having yielded in excess of 3,450,000 tons of ore valued at $48,750,000 (net smelter returns) to 1956.

It is located in the central part of the Main Tintic mining district approximately at the south-central edge of Eureka townsite. The massive dump of the Chief No. 1 shaft dominates this section of Eureka and can be seen from every part of town.

The total property of the Chief Consolidated Mining Company in the Tintic mining districts include more than 10,000 acres of patented claims and mining rights, but the workings of the Chief mine penetrate and explore only a small part of this large acreage. The mine is developed by two surface shafts, four principal underground shafts (winzes), approximately 120 miles of drifts, crosscuts, raises and winzes, and many thousand feet of open stopes. The No. 1 shaft is the main operating entry to the mine; it is a two and one-half compartment vertical shaft 1850 feet deep. Seven levels are turned from this shaft at 200-foot intervals from the 600 level to the 1800 level. The No. 2 shaft is located 3600 feet northeast of the No. 1 shaft; it is a two-compartment vertical shaft 1800 feet deep and is used chiefly as a ventilation and escape shaft. The principal underground winze, the 18-411 winze, is located in the northeastern part of the mine. It extends from the 1800 level to the 3050 level and consists of two hoisting compartments and a partial compartment for water, air columns and electrical cables. Eleven levels are turned from this winze at 100-foot intervals from the 2000 level to the 3,000 level. The mine workings are mostly beneath the central and eastern

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part of Eureka townsite, but some continue several hundred feet north, south and east of the townsite boundary.

The elevation of the collar of the No. 1 shaft is 6577 feet, and the elevation of the sill of the 3000 level is approximately 900 feet below the surface of Utah Lake, and approximately 610 feet below the surface of Great Salt Lake (see Figure 8).

ACKNOWLEDGEMENTS

Acknowledgement is given to Mr. Cecil A. Fitch Jr., president and general manager of the Chief Consolidated Mining Company, for permission to publish the company maps and data contained in this report. Other data were taken from notes, maps, reports, and oral statements by Messers M. J. Pitts, G. W. Crane, Paul Billingsley, R. N. Hunt, M. B. Kildale, H. G. Peacock, L. C. Crammer, W. G. Stevenson, J. G. Hall, and Hal T. Morris.

HISTORY

The first development of the Chief mine took place in 1906 when the Little Chief Mining Company undertook the sinking of the Chief No. 1 shaft. Mr. Walter Fitch Sr. reasoned that the ore bodies which had been followed northward from the Mammoth mine through the Grand Central and Victoria mines to the Eagle and Bluebell mine (developed during the early 1870's) probably extended northward beyond the Eagle and Bluebell property line; in 1909 Mr. Fitch and associates gained control of the Little Chief property, reorganized it and renamed it the Chief Consolidated Mining Company. His reasoning proved correct when, in 1910, ore was encountered on the 1400 level of the Chief mine a few hundred feet northeast of the No. 1 shaft.

As the 1400 level ore bodies were explored and developed it became apparent that the Mammoth-Chief ore zone extended northward beneath Eureka townsite. The Chief Consolidated Company then laid plans to acquire the mineral rights to each individual building lot within the townsite. Several thousand individual mining agreements eventually were signed, some in exchange for Chief Consolidated common stock.

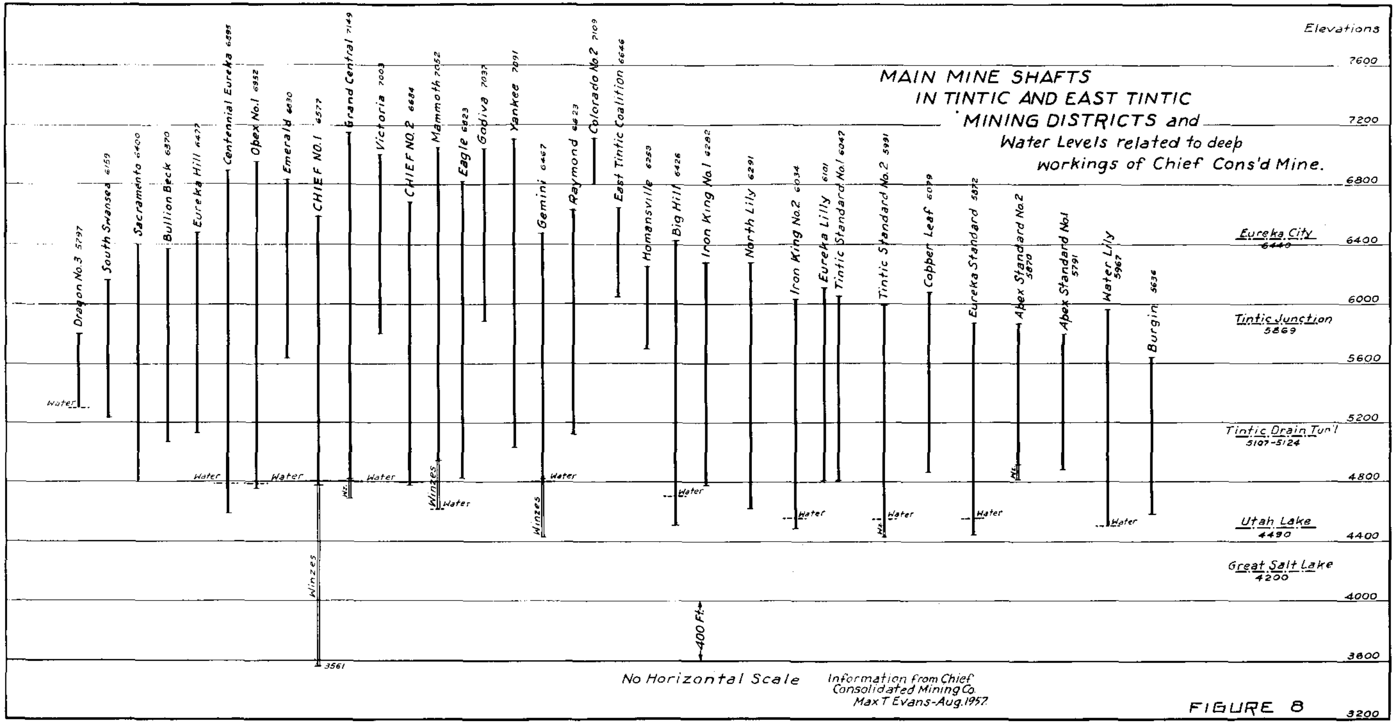

MAIN MINE SHAFTS
IN TINTIC AND EAST TINTIC
MINING DISTRICTS and
Water Levels related to deep
workings of Chief Cons'd Mine.
Elevations
7600
7200
6800
6400
6000
5600
5200
4800
4400
4000
3800
3200
Eureka City 6440
Tintic Junction 5869
Tintic Drain Tun'l 5107-5124
Utah Lake 4490
Great Salt Lake 4200
Dragon No.3 5797
South Swansea 6159
Sacramento 6400
Bullion Beck 6370
Eureka Hill 6422
Centennial Eureka 6395
Opex No.1 6952
Emerald 6630
CHIEF NO.1 6577
Grand Central 7149
Victoria 7003
CHIEF NO.2 6684
Mammoth 7052
Eagle 6823
Godiva 7037
Yankee 7091
Gemini 6467
Raymond 6623
Colorado No.2 7109
East Tintic Coalition 6646
Homansville 6253
Big Hill 6426
Iron King No.1 6282
North Lily 6291
Iron King No.2 6034
Eureka Lilly 6101
Tintic Standard No.1 6047
Tintic Standard No.2 5991
Copper Leaf 6079
Eureka Standard 5872
Apex Standard No.2 5870
Apex Standard No.1 5791
Water Lily 5967
Burgin 5634
Water
Winzes
3561
400 Ft.
No Horizontal Scale
Information from Chief Consolidated Mining Co. Max T Evans-Aug. 1957

FIGURE 8

Prior to 1916 all of the ore bodies mined were in the oxidized zone above the water table which originally stood about 20 feet below the 1800 level. At this time the first pumps were installed, and between the years 1916 and 1927 sulfide ores were mined to the 2500 level.

In 1927 depressed metal prices and high operating costs forced the abandonment of the pumping operation, and the mine filled with water to a point about 40 feet below the 1800 level. Through the "depression years" the mine was operated somewhat intermittently. During part of this interval the mine was worked by the employees as a community lease; this interesting experiment in "communism" ended quite unsuccessfully.

In 1942, during the early part of the United States participation in World War II, the government incentive plan for zinc and lead made it again feasible to de-water the mine and extract the great bodies of ore that were known to occur below the water table. De-watering operations began in August 1942; deep-well and centrifugal pumps were installed, and by 1947 the mine workings had been extended below the 2700 level. In 1951 a complete new pumping system was installed and the workings were further deepened to the 3050 level. In September 1954 low metal prices and high operating costs, coupled with other factors, again forced the company to abandon the deep levels. However, the mine continued to ship ore from the upper levels until June 15, 1957 when all operations were temporarily suspended because of continued depression of the lead and zinc market.

ROCK UNITS

General Statement

The Chief mine workings explore the faulted steep western limb and axial area of the Tintic syncline. The greater part of the surface adjacent to the Chief No. 1 and No. 2 shafts is underlain by colluvium and fanglomerate. The No. 1 shaft penetrates 60 feet of this material and 300 feet of Packard quartz latite before it cuts the Victoria formation which it follows to the 1800 level.

Ore bodies have been mined from the Eagle and Bluebell-Chief property line northward for more than 5000 feet.

They are localized chiefly along bedding plane faults, but they expand greatly in size and commonly become pipe-like at the intersection of the bedding plane faults with steeply dipping, northeasterly and easterly-trending transverse faults. Locally they follow these faults for considerable distances.

Plate 7 is a geologic plan map of the Chief mine 1000 level with projected ore bodies, and plate 8 is a longitudinal section of the Chief ore zone.

Sedimentary Rocks

The sedimentary rocks exposed in the Chief mine range in age from Ordovician to Mississippian; they are listed in Figure 9.

Igneous Rocks

The lavas that are penetrated by the Chief No. 1 and No. 2 shafts include the basal tuff member, the lower vitrophyre member and the massive quartz latite flow member of the Packard quartz latite. A total thickness of 1600 feet of these rocks is cut by the No. 2 shaft. Extrusive rocks older than the Packard quartz latite have been reported from the Chief mine by other geologists, but these rocks are believed to be units of the Packard that were highly altered by the late pre-ore hydrothermal solutions.

The most prominent intrusive rock exposed in the Chief workings is a plug of andesite or basic latite porphyry that intrudes the Opohonga limestone in the west-central part of the mine. A fine-grained, highly altered dike, presumably related to this plug, follows the Leadville fault zone through the northern part of the developed area. Several other highly altered bodies of intrusive rock have been cut in the central and southern parts of the mine. These rocks have not been studied in detail but are believed to be quartz monzonites.

STRUCTURE

FOLDS

The Tintic syncline is the dominant structure exposed in the mine. The west limb of this fold dips steeply to the east and locally is overturned. On the 1800 level, a few hundred

SYSTEM	FORMATION		UNITS DIFFERENTIATED ON UNDERGROUND MAPS	THICKNESS (Feet)
Mississippian	Deseret or Pine Canyon limestone (lower part)		“Tetra” limestone	335
			Black carbonaceous shale	150
	Madison or Gardner limestone	Upper member	Gray fossiliferous limestone	160
			Blue “ “	90
		Lower member	Blue concretionary limestone	2
			Fine-grained pink “	6
			Sugary-grained dolomite	72
			Black, cherty “	64
			Blue shaly limestone	38
			White limestone	31
			Upper blue flaky limestone	44
Devonian	Pinyon Peak limestone		Lower blue flaky limestone	76
	Victoria formation		Mottled dolomite	72
			Sandstone and dolomite	209
Silurian	Bluebell dolomite		“Noah” dolomite	290
			“Dora” dolomite	212
			Upper “Beecher” dolomite	192
Ordovician	Fish Haven dolomite		Lower “Beecher” dolomite	20
			“Eagle” dolomite	180
	Opohonga limestone		(White lime shale)	857

Modified from G. W. Crane and U. S. G. S.

Fig. 9. GENERALIZED STRATIGRAPHIC SECTION OF SEDIMENTARY ROCKS EXPOSED IN CHIEF MINE.

feet north of the No. 1 shaft, the limb flattens abruptly, forming a wide trough that plunges to the north at 10° to 30°. The axis of the fold trends slightly east of north in the Chief mine area.

Several subsidiary folds have also been exposed in the Chief mine workings. One of these folds, which localizes a large ore body in the American Star block of claims east of the No. 1 shaft, is a typical drag fold related in origin to the folding of the major syncline. Other minor folds occur close to faults and are believed to be fault-drag folds related to strike-slip movement on the larger transverse faults.

FAULTS

Four systems of faults are recognized in the Chief mine. They are classified according to their strike, since the movement along them is almost entirely pre-ore in age.

Northeast-trending Faults

The northeast-trending faults localize large ore bodies and appear to have been utilized locally as channelways by hydrothermal solutions. The northern-most of these faults is the Beck which is the dominant fault in the central part of the mine. It has been explored for over 8,000 feet along strike and 1500 feet down the dip. It strikes N. 55° - 70° E. and dips southeasterly at about 70°. The maximum displacement is estimated to be about 2000 feet near the Bullion Beck mine, but may be less than 1,000 feet in the Chief mine owing to the probable occurrence of subsidiary north-northeasterly-trending faults between the two mines. The movement along the Beck fault is essentially horizontal as is indicated by the off-set of key beds in the vertical limb of the Tintic syncline and occurrence of nearly horizontal mullions and striations on the slickenside surfaces adjacent to the fault plane.

The Millionaire Row fault is the next northeast-trending fault south of the Beck; it is economically less important than the Beck and has not been developed to as great an extent. The name "Millionaire Row" was applied to this structure because it localizes relatively small bodies of high-grade silver and lead ores which were mined by lessees, several of whom made considerable personal fortunes. The

Millionaire Row faults follows a somewhat sinuous course with an average strike of about N. 50°-75° E.; it dips 50° to 75° to the northwest, and has a small displacement, probably not more than 100 to 200 feet.

The dominant northeast-trending fault in the southern part of the mine is the Centennial. This fault strikes about N. 70° E.; in the upper part of the mine it dips southeasterly but at about the 1,000 level it reverses its dip to northwesterly. It is believed to have originated as a strike-slip fault, but also shows a large amount of vertical displacement, with the north block down more than 1,000 feet.

Northwest-trending Faults

The northwest-trending faults are fewer and far less important as ore-controlling structures than those with northeast trends. The only large northwest-trending fault that localizes ore in the Chief mine is the Bulkhead fault. This structure extends between the Beck and Millionaire Row faults in the west-central part of the mine, and at its intersection with the Beck appears to localize part of the 18-316 ore body. The Bulkhead fault trends approximately N. 75° W. and dips to the southwest at 65° to 85°.

It is believed that the northwest-trending faults were formed early in the deformation of the rocks, and later tectonic stresses sealed the openings and compacted the breccia zones prior to ore deposition. For this reason little ore is found along them.

East-trending Faults

The only major east-trending fault in the Chief mine is the Leadville fault which intersects the Beck about a thousand feet northeast of the 18-411 winze. The Leadville is a reverse fault with about 800 feet displacement; it dips steeply to the south. Throughout most of its known length the fault zone is occupied by a thin dike of highly argillized andesite porphyry. This dike may have been injected along the Leadville fault sometime during the interval that the ores were being deposited.

Bedding-Plane Faults

Bedding-plane faults are common in both the steep western limb and the flat, north-plunging trough of the Tintic syncline. Because these faults are parallel with the bedding, they are not as obvious as the cross-bedding faults, but several of them localize large segments of the persistent, north-trending zone of connected ore bodies, and thus rank with the Centennial, Beck and Millionaire Row faults as the more important ore localizing structures in the mine.

ORE DEPOSITS

General Description

The ore deposits of the Chief mine constitute the northern end of the spectacular Chief ore zone (see Plate 8). At the southernmost part of the mine, this zone intersects the Centennial fault and forms a large, pipe-like body of ore known as the Granite chimney (see Plate 7). This ore body averages about 75 feet in diameter and extends from the 600 level to below the 1400 level of the mine. The ore is found in the "white" limestone unit of the lower member of the Madison limestone where it is crumpled against the fault plane.

Northward from the Granite chimney, the ore zone follows steeply dipping, north-trending, bedding plane faults that are localized in the lower member of the Madison limestone; it plunges from an elevation of 5600 feet near the Centennial fault to 4600 feet near the Beck fault zone. At the point, within this interval, where it crosses the Millionaire Row fault, the ore zone is enlarged both in plan and section, and small vein and pipe-like ore bodies extend northeasterly along the fault zone. However, the principal orebodies extend across the Millionaire Row fault and follow the bedding plane faults.

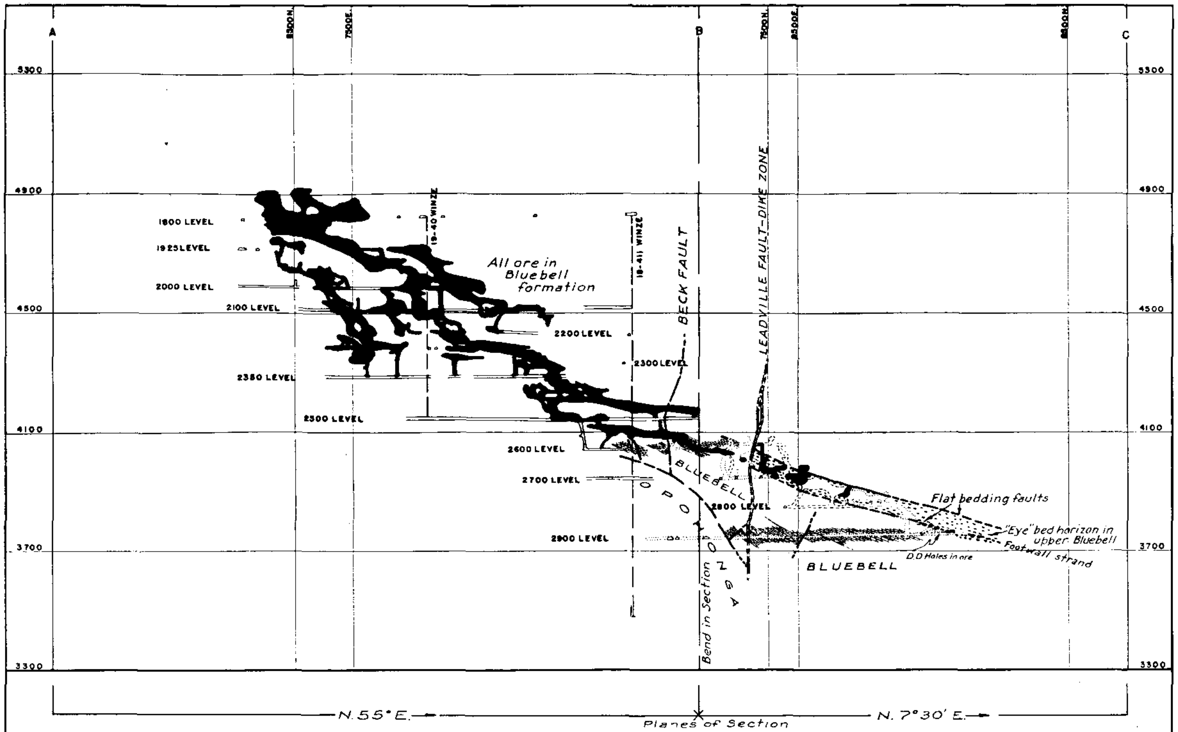
At the intersection of the main ore zone and the Beck fault, the ore zone is greatly enlarged and forms the 18-316 ore body, the largest individual ore body thus far found in the mine. In plan this ore body is shaped like a large crab with a bulbous central "body" portion and four "legs" (plunging, linear ore zones) that extend northward and northeastward along faults and favorable bedding horizons.

The two westernmost of these channels have been mined from the 1800 level to the 2200 level of the mine, but they are much smaller in size and lower in grade than the more extensively developed eastern channels referred to as the "C Sump" zone and the "Beck" zone.

The ore bodies of the "C Sump" zone branch off the 18-316 ore body at about the 1950 level and plunge at a low angle in the Bluebell dolomite to a point a short distance south of the Leadville fault where they plunge nearly vertically, in the lower Bluebell and Fish Haven dolomites, to about the 2700 level. At this elevation they extend through the Leadville fault and for a short distance plunge steeply down the north side of the Leadville fault in the lower part of the Victoria formation to a low dipping bedding plane fault near the top of the Bluebell dolomite where they join the northernmost-mined ore bodies of the Beck Zone.

The Beck ore zone, the largest of the four north-trending ore zones, leaves the 18-316 ore body at the 1950 level and rakes down the Beck fault zone for approximately 1800 feet (see Figure 10). At this point, the zone splits and the larger branch follows the "Northeaster" fissure, a fault of small displacement that extends between the Beck and Leadville faults near the acute angle intersection of these two structures. The Beck zone ore bodies are somewhat enlarged near the Leadville fault, but extend through it at about the 2600 level and follow low dipping bedding plane faults in the Bluebell dolomite in the block north of the Leadville fault. The ore bodies localized by the bedding plane faults trend northward and northeastward and have been mined to the 2800 level where adverse economic conditions forced their abandonment.

In the east-central part of the mine about 700 feet east of the main ore zone, a sub-parallel ore zone has been mined from the American Star claims to the Millionaire Row fault. These ore bodies are highly siliceous and in general are lower in grade than the ore bodies of the main ore zone. The American Star ore zone rakes from about the 1,000 level of the mine to below the 1800 level where it intercepts the Millionaire Row fault. The ore bodies apparently turn along this fault, and have been developed to the northeast along the Millionaire Row fault to the 2700 level of the mine. Lo-



DETAILED SECTION of the DEEP ORE ZONE of the CHIEF MINE

VERTICAL SECTION ALONG LINE A-B-C
SHOWING GEOLOGY AND STOPING ALONG THE BECK FAULT ZONE, AND DEEP NORTH-SOUTH ORE ZONE.

SCALE
0 100 200
FEET

ON PLANE OF SECTION
PROJECTED TO PLANE OF SECTION

FIGURE 10
Information from Chief Consolidated Mining Co.
Max T. Evans, Aug. 1957.

cally some of the ore bodies of the American Star zone extend northerly through the Millionaire Row fault zone, and merge with the ore bodies of the Beck sub-zone.

Mineralogy and Zonation

The ores produced from the Chief mine consisted of almost equal amounts of oxidized ore mined above the 1800 level and primary and secondary sulfide ores mined below the permanent water table about 20 feet below the 1800 level. The primary ores are composed chiefly of pyrite, galena and sphalerite with minor quantities of argentite, native silver and gold in a gangue of brecciated, vuggy, baritic jasperoid. The sulfide ores, found approximately between the 1800 and 2000 levels, contained much galena, wurtzite and native silver, and were the principal "dividend paying" ores of the mine. The oxidized ores were locally very rich in horn and native silver, but consisted chiefly of cerussite, anglesite, and plumbojarsite in a gangue of iron stained jasperoid breccia. Oxidized copper minerals were abundant in some parts of the Granite chimney and these ores were comparatively rich in gold. Zinc was not commonly found in the oxidized ore bodies but large tonnages of high-grade secondary zinc ore obviously representing zinc removed from the overlying ore bodies during the oxidation processes were mined in the area immediately below the 18-316 ore body.

Many of the ore bodies mined on the 2350 level, some 500 feet below the water table, were also more or less oxidized These ore bodies were characterized by relatively high values in copper and gold, moderate values in lead and silver and low values in zinc. As the ore zone was followed northward, copper and gold values decreased and the value of lead, silver and zinc increased. Near the water table in the zone of secondary enrichment lead and silver values predominated, zinc was also important and copper and gold were subordinate. Northward and below the zone of secondary enrichment, zinc equaled or predominated over lead, and silver decreased until the silver-lead ratio (ounces per ton to percent) approached one. In the extreme deep ore zones of the mine, zinc was the predominant metal in the ore; silver and lead remained constant, but a slight increase in gold and copper was apparent.

Classification and Genesis

The ore bodies of the Chief mine are typical "limestone replacement" deposits. They are irregular and tortuous in form, but have been proven to be interconnected and form runs or zones of great persistence. The great vertical range and zoning of the ore bodies, and the absence of high temperature minerals and the estimated moderate depth of the ore bodies below the surface at the time of their formation place them in the class of mesothermal deposits.

The general form and mineralogic composition of parts of the ore zone indicate that multiple channelways were used by the ascending ore solutions. Several of the chimney-type ore bodies occur directly over intrusive igneous rocks, and the country rock underlying some of the deeper ore bodies, especially those along the deep breaking faults, is strongly altered indicating that the ore depositing solutions rose steeply from great depth and followed interconnected open spaces of many types.

PRODUCTION

The quantity, metal content and value of ore produced from the Chief mine from 1909 to 1956 are summarized in Figure 11. Complete production data can be found in the Annual Reports of the Chief Consolidated Mining Company.

From the standpoint of the quantity of ore produced, the Chief mine is the most productive mine in the East Tintic Mountains; however, the profits have been much smaller than those of the Tintic Standard mine. The ore bodies of the Chief are perhaps more noted for their large size and great persistence rather than their grade, but small bodies of exceptionally high-grade silver ore are not uncommon.

Outlook for Future Production

The Chief mine has produced a large quantity of ore, but it currently is not in operation. Much undeveloped ground remains with many geologically attractive targets. Doubtless the mine will some day be re-opened, but its future and the future of the entire district rest solely on economic, not geologic, factors.

INTERVAL	DRY TONS	GOLD ozs.	SILVER ozs.	LEAD lbs.	COPPER lbs.	ZINC lbs.	NET FROM SMELTERS
1909 to 1919	453,547	50,067	12,369,776	62,823,420	382,383	2,188,373	$ 8,726,120.64
1920 to 1929	1,158,389	91,161	27,294,824	193,646,964	7,732,180	19,881,986	$21,916,080.18
1930 to 1939	246,702	16,609	3,358,666	13,178,494	1,438,156	4,886,472	$ 1,649,992.48
1940 to 1949	817,087	23,142	4,649,394	63,954,012	714,880	77,337,186	$ 8,464,129.75
1950 to 1956	776,055	19,517	4,425,463	76,937,192	610,616	61,417,825	$ 8,014,617.29
Totals	3,451,780	200,496	52,098,123	410,540,082	10,878,115	165,711,842	$48,770,940.34

Figure 11. GENERAL SUMMARY OF PRODUCTION FROM THE CHIEF MINE.

GEOLOGY OF THE HALLOYSITE DEPOSIT AT THE DRAGON MINE

By

M. B. KILDALE and R. C. THOMAS

INTRODUCTION

The Dragon mine is located near the northeast corner of the main Silver City monzonite stock, at the point where the Dragon fissure passes southerly from limestone into the igneous rocks. During the early days of mining at this property a large irregular deposit of iron oxides was mined by open pit methods, the ore being used as a flux in the smelting of the siliceous ores obtained from the Colorado-Humbug ore "channel." It was noted at that time that the iron oxide deposit was bordered in places by a massive white, somewhat shiny or "greasy" material, then called "talc" or "clay." About the turn of the century the Dragon shaft was sunk near the monzonite-limestone contact to explore for additional iron-oxide deposits by means of underground headings and, later, drill holes. Some of these headings and drill holes also penetrated thick sections of alternating limestone, iron oxide and "talc."

After control of the property was obtained by the International Smelting and Refining Company in the twenties, attempts were made to identify the "clay" material and to find a market for it in the ceramic, foundry or other industries. Geologic mapping at the time made it clear that this "clay" material was a hydrothermal replacement, chiefly of the limestone, and that a large tonnage of very pure material existed here. In the late thirties X-ray investigations showed that the material consisted largely of the mineral halloysite (Schroter, 1942). It was not, however, until after extensive research by the Filtrol Corporation that a profitable use was found and mining begun in 1949. Up to the present time nearly 500,000 tons of halloysite have been extracted from this deposit, which is now under option to, and being mined by, the Filtrol Company. The halloysite "ore" is treated at the Filtrol plant in Salt Lake City to make a product used as a catalyst in the refining of certain types of

crude oils. It is believed that its unique value for this purpose lies in the unusual "tubular" crystal structure of the halloysite (Kerr, 1950).

GEOLOGY and MINERALOGY

The halloysite or "Dragon clay" deposit, as mentioned above, occurs as a large, massive but somewhat irregular replacement of altered limestone along, or close to, the contact with the igneous rocks to the south. In this area a southeast-trending lobe of limestone is surrounded on the west, south and east by monzonite-porphyry (see Plate 10) and in this area also the contact is intersected by the Dragon vein and other northeast-striking mineralized fissures. The intrusive contact dips to the east and to the south so that beneath the surface the limestone is overlain by the igneous rocks. At the eastern end of the halloysite-bearing area the monzonite has intruded and altered earlier latite flow rocks which also lap up against the limestone. It is postulated that this extensive and complete argillic and pyritic replacement of the limestone was due to hydrothermal solutions rising along the northeast fissures and being "trapped" under an overhanging "roof" of igneous rocks.

The sedimentary rocks exposed in the halloysite area are included in the Ajax formation and the lower part of the Opohonga formation, the contact being exposed on the surface north of the open pit (see Plate 11). Close to the intrusive rocks, the limestones are partially metamorphosed, being extensively recrystallized and locally silicated, although such minerals as garnet are rare. The beds strike southeasterly and dip to the east at an average inclination of about 20°. Most of the replacement by halloysite and associated minerals has taken place in the upper part of the Ajax formation where the original bedding planes are locally distinctly visible in the "clay." Rows of unreplaced chert nodules also show the location of original cherty beds in the limestone.

At the surface the halloysite deposit occurs as two irregular "pipes" separated by a zone of mixed iron oxide and "clay" along the Dragon fissure (see Plate 11). The two pipes of purer halloysite plunge steeply from the surface to about the 230 level but on the 300 level the bedding control is more

pronounced and the general trend of the replacement is northwesterly, nearly parallel to the strike of the replaced rocks (see Plate 10). Local bedding control is also evident in and around the pipe-shaped bodies on the upper levels.

Mineralogically the typical fresh material from this deposit consists of nearly pure halloysite containing very finely disseminated pyrite which is often invisible to the naked eye. When exposed to the air the oxidation of the pyrite imparts first a faint pinkish tinge to the white halloysite and, on further exposure, a reddish brown color with prominent iron oxide stains on the fractures. The purest material, when fresh, has a white color and a lustrous porcelain-like appearance but often grades into a duller dense to fine-grained, white variety. Both forms of halloysite are present, the less hydrous form ($Al_2O_3 .2SiO_2 .2H_2O$) and the hydrated form, also known as endellite ($Al_2O_3 .2SiO_2 4H_2O$ (Kerr, 1949). Gibbsite has also been reported in small amounts.

In the weathered exposures, both close to the surface and at greater depths along fissure zones, iron oxides are universally present, with less common stains of manganese oxides, and the amount of these impurities is important from an economic standpoint. Around the margins the massive halloysite grades irregularly into unreplaced limestone or into relatively pure masses of iron oxide containing little "clay."

The present limited amount of development work below the 300 level is not sufficient to indicate what the total tonnage of this material may be, but, as developed to date, it is apparently the largest known massive concentration of nearly pure halloysite.

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INTRODUCTION TO THE GEOLOGY AND ORE DEPOSITS OF THE EAST TINTIC MINING DISTRICT

By

JOHN B. BUSH

Bear Creek Mining Company

GENERAL STATEMENT

For the purpose of this Guidebook the East Tintic district is roughly defined as that area within the Eureka, Utah quadrangle which lies east of meridian 112° 05′ and south of an east-west line through Packard Peak. The relief is moderately rugged with the highest peaks in the western and northern parts of the area rising to elevations of 6500 to 7000 feet and sloping off rather gently eastward to elevations of about 5500 feet. Plate 12 is a plan map showing the subsurface geology, structure and main ore bodies in the East Tintic district.

The first ore was discovered in the East Tintic district in 1909 from fissure veins cut by the Eureka Lilly shaft. The first major ore discovery was made in 1916 by E. J. Raddatz after nine years of shaft sinking and crosscutting. This led to the great Tintic Standard "pothole" ore body which later proved to be the richest of all the Tintic mines. Aggressive geological exploration later led to the principal ore bodies of the North Lily and Eureka Lilly mines in 1927 and the ore bodies of the Eureka Standard mine in 1928. Except for extensions of these main ore bodies there have been no new large deposits discovered since that time.

The East Tintic district has produced metals having a gross value of approximately $113,000,000. Of this production, approximately 41 percent of the value has been in silver, 29 percent in gold, 27 percent in lead and 3 percent in copper. The majority of the gold-copper ore came from fissure-type deposits in the Tintic quartzite while the bulk of the lead-silver ore was produced from oxidized limestone replacement deposits within the middle Ophir limestone. The fissure ore has accounted for 27.4 percent of the total production while the replacement ore has accounted for 72.6 percent.

The main producers in the East Tintic district were the Tintic Standard, North Lily, Eureka Standard, Eureka Lilly and Apex Standard mines. The Tintic Standard was by far the largest producer, having a gross of $80,000,000. The North Lily, Eureka Lilly and Eureka Standard produced $30,000,000. Production from the other properties was relatively minor. None of the East Tintic mines are active at the present time.

GENERAL GEOLOGY

Sedimentary Rocks

The entire East Tintic area is underlain by Paleozoic sediments. In only relatively small areas do the sediments occur at the surface as windows in the volcanic cover. Only the lower part of the sedimentary column (from Cambrian quartzite up through the Ordovician-Silurian Bluebird formation) is present in the East Tintic district as younger formations have been eroded. In the eastern part of the district, however, it is believed that a much thicker section of sedimentary rocks (from Cambrian quartzite up through the Mississippian-Humbug formation) occurs in the footwall side of a large north-striking thrust(?) fault.

Igneous Rocks

Most of the East Tintic district is covered by a thick series of extrusive volcanic rocks of Middle Eocene age. The general succession of events began with the extrusion of the Packard rhyolite series including porphyritic latite, latite, vitrophyre, rhyolite, tuffs and flow breccias. This series was followed by the Laguna latite series, including black and red porphyritic latite, latite breccia, agglomerates and tuffs. From drill hole information and underground workings it is evident that the pre-lava land surface was of moderate relief and similar to the present topography.

The sediments and volcanics were later intruded by stocks, plugs and dikes of monzonite and quartz monzonite of Middle or Upper Eocene age. These intrusive bodies are aligned along a general northeasterly direction, appearing most frequently in a zone through the Zuma, Iron King No. 1 and North Lily mines. Pebble dikes, commonly having a north-

easterly trend, are contemporaneous with the monzonite dikes and are particularly abundant in the Trixie, North Lily and Homansville Canyon areas.

Structure

The most important structural feature in the East Tintic area is the north-plunging East Tintic anticline which is complementary to the Tintic syncline in the Main Tintic district. Although largely covered by volcanics, it is believed that the East Tintic anticline is asymmetrical, with a gently dipping western limb and a more steeply dipping eastern limb. The axis of this anticline can be traced in a general northerly direction from the Trixie area north through the Eureka Standard and into the Tintic Standard property.

The East Tintic anticline is transected by northerly-trending faults that have broken it into a series of grabens and horsts. Most of the faulting occurred before the ore was deposited and any post ore faulting is of relatively small magnitude. Practically all of the folding and faulting occurred before Late Cretaceous time, therefore, little or no reflection of faults and folds can be seen in the overlying Tertiary volcanics. Carbonate rocks are preserved in the grabens but were mostly eroded from the structurally higher horst blocks prior to the extrusion of the lavas. These grabens or structural troughs, where cut by mineralized fissures, have been favorable environments for most of the ore in the district.

At the extreme northern end of the district is the Homansville trough, formed by the northeast-trending, northerly-dipping Homansville fault and the easterly-trending, steeply-dipping Canyon fault. No limestone replacement ore has been found in this trough although mineralized fissures have been discovered in the Copper Leaf, Water Lilly and Central Standard mines.

South of the Homansville trough is a structurally high area of quartzite beneath rhyolite cover, termed by T. S. Lovering the "East Tintic barrier." This is bounded on the southwest by the Tintic Standard trough, which contains the Tintic Standard ore body, and the North Lily trough, which localized the North Lily and Eureka Lilly ore bodies. The Tintic Standard trough trends northeast and coalesces

to the east with the northwest-trending North Lily trough. At this intersection is formed the famous Tintic Standard "pothole" structure. These troughs are bounded on the south by the north-dipping South fault, on the north by the south-dipping East (Standard-Lily) fault and on the west by the north-striking, westerly-dipping Eureka Lilly fault. T. S. Lovering (1949, p. 14) interprets the South and East faults as a folded thrust which he termed the Tintic Standard fault. These important trough structures and their related ore deposits are described in more detail by M. B. Kildale in a following paper.

In the southern part of the East Tintic district is the northeast-trending Eureka Standard trough, margined by the high-grade gold fissure ore of the Eureka Standard mine and the much smaller ore bodies of the Iron King and the Apex Standard mines. No limestone replacement ore has been discovered in this trough. It is bounded on the north by the south-dipping Iron King fault and on the south by the north-dipping Eureka Standard fault. A newly discovered structure, the Chief Oxide fault may terminate this trough to the east.

Immediately to the south of the Eureka Standard trough is the little prospected, northeast-trending Apex Standard trough. It is formed by the reverse, north-dipping Apex Standard fault and the north-dipping Teutonic fault. The northeastern limit of the trough is not known but like the Eureka Standard trough is probably terminated by the Chief Oxide fault. Drilling results of Bear Creek Mining Company suggest that the Eureka Standard fault trends in a more southerly direction from its last known position in the Eureka Standard mine and thus may terminate the Apex Standard trough to the west. No limestone replacement ore has been found in the trough although mineralized fissures were discovered in drifts that penetrated it from the Apex Standard No. 2 mine.

The eastern part of the district is covered by extrusive rocks and structural information regarding the underlying sediments is very vague. From drill hole data and exposures in the Burgin shaft, however, it appears that large-scale thrust faulting has developed along the eastern limb of the East Tintic anticline, resulting in a plate of Cambrian rocks

being moved eastward over younger Devonian-Mississippian rocks.

One of the most important structural features, from an economic point of view, is the system of minor northeasterly fissures. These fissures are often mineralized and must have acted as channelways or conduits for mineralizing solutions from depth. Cutting through sediments, these fissures commonly extend up through the volcanics to surface. They are frequently filled with pebble dike material or jasperoid. These fissures are particularly abundant in the Tintic Standard and North Lily mines and also in the Eureka Standard and Trixie areas.

GUIDES TO ORE

A brief summary of geologic conditions guiding the search for ore in the East Tintic district is presented below:

1. The middle Ophir limestone where faulted against Tintic quartzite is a particularly favorable environment for lead-silver replacement ore. This situation usually exists in the district in down-faulted trough structures such as the Tintic Standard, North Lily and Eureka Standard troughs.

2. Fissure veins, because they represent conduits for mineralizing fluids, are important ore guides, especially where they enter the structures described above.

3. Large normal or thrust faults may be mineralizing structures in themselves or may provide the necessary brecciation, porosity and permeability for the transfer and precipitation of ore. An area of convergence of two or more fault structures provides particularly favorable conditions. Fold and crumple structures within the troughs may also provide the necessary rock preparation.

4. Pyritic, calcitic and jasperoid alteration in volcanic cover are general indications of zones of late stage hydrothermal activity and possibility of ore bodies in underlying carbonate formations. Sanded dolomite and baritic jasperoid in the carbonate rocks also represent late stage hydrothermal effects and serve to guide exploration.

5. Where limestone replacement ore bodies are found adjacent to intrusives they are characterized by high lead and

zinc and low silver while those ores at intermediate distance contain a greater proportion of the more profitable silver.

6. Fissure veins have produced important amounts of gold, silver and copper in the district and appear to be more prolific when the ores are found near to igneous centers. Almost universally they have the Tintic quartzite as a host rock.

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ORE DEPOSITS OF THE TINTIC STANDARD, NORTH LILY and EUREKA LILLY MINES

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HISTORY AND PRODUCTION

Following the discovery of the first great mines of the Main Tintic district, between the years 1869 and 1896, some of the early-day miners and prospectors began to devote their attention to the large area lying below and to the east of the main range. The terrain here, however, was quite different from that along the crest of the mountains where the ore discoveries had previously been made, for the rolling hills of the east slope were carved largely out of a blanket of younger volcanic rocks with only a few "islands" of limestone protruding through the barren flows. Some areas of monzonite porphyry were also found here but these contained no strong quartz veins such as those of the Swansea or Sunbeam mines in the Silver City stock. Certain limestone areas, however, did show evidence of mineralization, usually close to contacts with monzonite or rhyolite, and the first prospect holes were dug in these outcrops of iron oxide, manganese oxide and jasperoid. No ore was found at the "grass-roots," however, and sampling of the outcrops universally indicated a lack of commercial amounts of precious or base metals. Thus it was that not until after the first real underground exploration work was started about 1909 that any ore was actually found in the East Tintic area (at the Eureka Lily shaft) and not until much deeper exploration work was completed at the Tintic Standard mine in 1916 was there any indication of the great ore bodies which existed in the Paleozoic sediments beneath the volcanics.

Looking backward, it is apparent that, even to a trained geologist, the surface exposures alone afforded but meager evidence of the complex structures within the pre-volcanic rocks and of the relationship of visible alteration

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and weak mineralization to these structures. It is interesting to note, however, that some of the pioneer prospectors in this area were intrigued by the areas of bleaching and alteration in the Packard rhyolite, particularly in the North Lily-Tintic Standard area, where they observed that the flows were cut by monzonite-porphyry dikes, with parallel zones or "reefs" of silicified and altered rhyolite. It is a strange coincidence that one of the early shafts was sunk to a depth of 90 feet within one of these zones at a point vertically above the main North Lily ore body which lay concealed beneath the volcanics some 750 feet below the bottom of the prospect shaft.

As noted above, the first ore to be produced in the East Tintic district was probably the oxidized lead ore mined in 1909-1910 from a fissure in the limestone, exposed on the 230 level of the Eureka Lilly shaft (Lindgren and Loughlin, 1919). All of the ore shoots found here were small, however, and it was not until Mr. E. J. Raddatz, an experienced and persistent miner, sank the nearby Tintic Standard No. 1 shaft to a depth of over 1000 feet and followed low-grade mineralization into the great Tintic Standard ore body that regular production began. The first ore was mined in the No. 1 shaft workings in 1913 and the main ore body encountered late in 1916. Thereafter the profits from this great silver-lead deposit supplied much of the capital and all of the incentive for additional underground exploration — which resulted in the discovery of the other mines of the East Tintic district, particularly the North Lily mine late in 1926, and the Eureka Standard mine in 1928.

Mine production from the small area which includes the Tintic Standard mine, the North Lily mine and the original Eureka Lilly property, between the years 1910 and 1950, has totaled approximately 3,100,000 dry tons of ore, from which there were recovered in the smelters over 300,000 oz. of gold, approximately 65 million oz. of silver, 700 million pounds of lead, 27 million pounds of copper and over 5 million pounds of zinc. Of this total tonnage, slightly over 2,400,000 tons was extracted from the Tintic Standard mine, nearly 375,000 tons from the North Lily mine and about 250,000 tons from the Eureka Lilly property.

Approximately 95 percent of the ore mined in the Tintic Standard mine consisted of silver-lead ore occurring as re-

placement deposits in the Ophir formation. The overall average content of recoverable metals per ton in this ore was .04 oz. gold, 24 oz. silver, 12 percent lead and 0.4 percent copper. For metallurgical reasons this ore was largely separated into two classes — (1) silver-lead ore, with a recoverable content of about .035 oz. gold, 28 oz. silver, 20.0 percent lead and 0.3 percent copper, and (2) siliceous silver ore from which the average recovery was .045 oz. gold, 20.0 oz. silver, 4.0 percent lead and 0.5 percent copper. In addition to these types of silver-lead ore, there was a small tonnage of very rich oxidized silver ore and also a relatively minor production of siliceous gold-silver-copper ore mined from fissures in the Tintic quartzite. This pyrite-enargite-tetrahedrite ore had an average content of about .12 oz. gold, 19.0 oz. silver, 2.6 percent copper and 1.0 percent lead.

Total production of approximately 375,000 dry tons of ore from the North Lily mine included some 194,000 tons of lead-silver ore, 35,000 tons of lead-zinc ore and 146,000 tons of siliceous gold-copper and gold-silver ore. The bulk of the lead-silver and lead-zinc ores occurred as replacement deposits in the Ophir formation. The siliceous ores were mined largely from fissure zones in the underlying Tintic quartzite. The average recoverable metal content of the lead-silver ore was: 0.116 oz. gold, 12.6 oz. silver and 24 percent lead; of the lead-zinc ore—0.087 oz. gold, 10 oz. silver, 7.1 percent lead and 6.1 percent zinc; of the siliceous ore — 0.84 oz. gold, 5.2 oz. silver, 1.23 percent lead, and 0.85 percent copper. The siliceous ore included both high-grade gold-enargite ore and lower grade pyritic gold-silver ores. The average grade (recovered metals only) of the gold-copper ore only (65,000 tons mined along the End-line Dike fissure) was as follows: 1.326 oz. gold, 4.75 oz. silver and 1.37 percent copper. It will be noted that, in comparison with the Tintic Standard lead ores, the North Lily ores had a higher lead content but much lower silver-lead ratio and that the lead was accompanied by a higher proportion of zinc. It will also be noted that the siliceous gold-copper ores in the North Lily mine were much richer in gold; locally this enargite-native-gold ore as mined returned over $10,000 per ton and cut samples contained over 2,000 oz. of gold per ton.

Production from the Eureka Lilly property in the area adjacent to the North Lily mine, and worked through the North Lily shaft, totaled approximately 145,00 dry tons, including about 50,000 tons of lead-silver ore and 95,000 tons of siliceous gold-silver ore. The average recoverable metal content of the lead ore here was: 0.187 oz. gold, 6.5 oz. silver and 17.5 percent lead; of the siliceous ore — 0.40 oz. gold and 2.75 oz. silver. Thus the combined production from the vicinity of the North Lily shaft, including both North Lily and Eureka Lilly stopes, totaled about 520,000 tons.

In addition to the above-mentioned ore, approximately 100,000 tons of siliceous gold-silver-copper ore was mined between 1936 and 1951 in the Eureka Lilly property—from fissures in the Tintic quartzite along the South Fault zone. This ore contained an average of about 0.15 oz. gold, 8.0 oz. silver and 2 percent copper. An additional 5000 tons of lead ore is credited to the Eureka Lilly shaft area, giving a total production from this property of slightly over 250,000 tons, including approximately 100,000 tons of gold-silver-copper ore and 95,000 tons of siliceous gold-silver ore (both types mined from fissures in the quartzite) and approximately 55,000 tons of lead ore (largely from the Ophir formation).

GEOLOGY OF TINTIC STANDARD - NORTH LILY - EUREKA LILLY AREA

Stratigraphy

The sedimentary formations exposed, either underground or on the surface, in the Tintic Standard-North Lily area, range from the Tintic quartzite to the Opex formation. However, in relation to the ore deposits of the area, only the Tintic quartzite and the overlying Ophir formation are important. The ore bodies found in the Tintic quartzite are limited to those of the fissure type, occurring in or along steeply dipping, northeast-striking fissures. Such ore shoots, although important, have been the source of far less ore than those found in the Ophir formation, where the great lead-silver relacement ore bodies of the Tintic Standard and North Lily mines occur.

The Ophir formation in this area can be divided lithologically into three units — (1) the Upper Ophir shale, about

80 feet thick, varying in character from greenish-grey banded and blocky shale to more fissile shale with lenses of sandy shale, (2) the Middle Ophir limestone, about 150 feet in thickness, consisting largely of well-bedded, dark grey limestone with some interbedded grey calcareous shale, and (3) the Lower Ophir shale, about 175 feet thick, made up largely of blocky calcareous shale near the top, grading into sandy micaceous shale at the base and containing one limestone or dolomite bed near the middle.

Measured sections of the complete Ophir formation in this area vary from 400 to 430 feet. This formation conformably overlies the massive Tintic quartzite, usually with a sharp contact, although thin beds of shale are common in the uppermost 50 feet of the quartzite. The Ophir is overlain conformably by the relatively massive Teutonic limestone.

All of the great lead-silver replacement ore bodies are found in the middle limestone unit of the Ophir which has been replaced by ore for thicknesses of up to 70 feet in the North Lily mine and over 100 feet in the Tintic Standard mine. The portion of the Ophir limestone which overlies the ore bodies is often dolomitized, particularly in the Tintic Standard stopes, and is often leached, iron stained, and brecciated due to oxidization of sulphides and slumping following oxidation of the ore below.

The fact that this unit of the Ophir formation has been so favorable for replacement by ore is probably due to its chemical composition and its physical characteristics. The alternation of well to medium-bedded limestones with some shale beds caused the development of many small fractures and bedding slips during periods of faulting, which permitted easier access for the ore-forming solutions. Even where unaltered, the Ophir limestone frequently contains abundant seams and veinlets of secondary calcite which fills minor fractures crosscutting the beds.

The Upper Ophir shale is rarely mineralized but some ore has been mined from the lower Ophir unit, as in the North Lily "pot-hole" where the shale has been crumpled and brecciated by folding, faulting and intrusion of a monzonite sill prior to mineralization.

Igneous Rocks and Pebble Dikes

The igneous rocks of this area include the lower part of the Packard rhyolite series (mostly quartz-latite according to Lovering, 1949) and later intrusive plugs and dikes of monzonite-porphyry. In the North Lily mine a few narrow dikes of purplish latite are also exposed and cut the northeast-striking monzonite-porphyry dikes.

In this area the base of the Packard series is marked by a greenish agglomerate bed overlain by the typical quartz-latite flow rocks. On the surface the unaltered quartz-latite is purplish or bluish-purple in color and often somewhat porphyritic in texture, with phenocrysts of biotite, feldspar and quartz. The biotite is nearly always visible, the prominent feldspars include plagioclase and sanidine; quartz phenocrysts are often relatively few. Magnetite is abundant in some flows, being visible under the hand lens. Flow-structure is often conspicuous in large outcrops, giving to many of these a platy structure. The thickness of the Packard flows in this area, as determined by underground workings and drill holes, varies from 0 to 700 feet (see Plates 14 and 15).

On the North Lily property the flow rocks have been intruded by a small stock of monzonite-porphyry (North Lily stock on Plate 13), also by a series of northeast-striking monzonite-porphyry dikes and pebble dikes which are localized along a wide zone of steep fissures.

The North Lily stock is composed of a coarsely porphyritic rock, grey to greenish-grey in color, with prominent feldspars, subordinate biotite and hornblende and rare quartz phenocrysts. Only weak fissuring and mineralization have been found within this stock. It is, however, somewhat altered along its borders and is surrounded on the surface by a large area of intensely bleached and altered quartz-latite.

The northeast-striking dikes are well exposed in the North Lily mine where they are closely associated with some of the ore bodies. In general, the dikes are darker in color than the stock but vary considerably in appearance. In some exposures they are dark green in color, the only conspicuous phenocrysts being of biotite; in other exposures

they are grey in color, with prominent phenocrysts of feldspar and very minor visible biotite or other minerals. The dikes thus contain the same minerals as the typical monzonite but show greater variation in the relative amounts of these minerals and in texture. Considerable fissure-type ore has been mined along or in two of these dikes in the North Lily area, where later fissuring has cut the dikes or has occurred along or closely parallel to the walls. Within the Tintic quartzite, monzonite-quartzite breccias developed within the fissure zones are often mineralized. The rich gold-copper ores in the south end of the North Lily mine occur along the End-line Dike and lead ore was mined within the Ophir limestone along the Shaft dike in the Eureka Lilly mine.

Another noteworthy feature of the Tintic Standard-North Lily area is the abundance of the so-called "pebble dikes" (Farmin, 1934 and Kildale, 1938) particularly along the North Lily dike and fissure zone. These dikes most commonly occur here as tabular or lenticular bodies within the steeply-dipping northeast fissures or along the walls of the monzonite-porphyry dikes. In places they cut the monzonite dikes along planes of later fissuring. One development drift in the North Lily mine, driven along a northeast fissure within the Tintic quartzite, showed a typical pebble dike grading along the strike of the fissure into rubbly quartzite breccia and this in turn into an open vuggy fissure containing gold-silver ore. The typical pebble dikes are often mineralized but rarely have been mined as ore, due to the fact that where reached by the mineralizing solutions, they were frequently tightly cemented by the earliest solutions which carried only silica and pyrite and were thus sealed off from the later solutions carrying most of the valuable metals.

The pebble dikes thus represent a stage of intrusion or injection which is later than the intrusion of the monzonitic rocks and earlier than the first stages of mineralization.

On the surface a conspicuous geological feature of the North Lily property is the large area of bleached and altered (argillized) quartz-latite which surrounds the North Lily stock. This alteration was one of the features which first focused geological attention on this property. Mapping of the fissure zones exposed within this area, together with

the working out of the sub-latite structure by means of diamond drilling and the projection of structures from the Tintic Standard area, led to the underground exploration work which resulted in the discovery of the North Lily ore bodies. The alteration of the flow rocks over the Tintic Standard mine is not so intense nor so conspicuous as in the North Lily area, being largely of the pyritic type as defined by Lovering, (Lovering, 1949) bordered by the calcitic type. For more complete and detailed information regarding rock alteration in this area the reader is referred to Lovering's Monograph on this subject and to other papers in this bulletin.

Structure

The great concentration of metallic ores in the Tintic Standard-North Lily area has clearly resulted from the introduction of an unusually strong and rich surge of metal-bearing solutions into ground which had been previously prepared structurally by two periods of deformation.

The first of these periods of deformation occurred in pre-latite time (Upper Cretaceous?) when west to east compression caused the formation of the main Tintic syncline. To the east of this syncline, in the East Tintic area, there was developed an irregular arch or anticlinal fold, now highly broken by faulting, which brought the Tintic quartzite to, or nearly to, the elevation of the present surface. This anticlinal structure has a general north-northwesterly trend but along its axis the quartzite and overlying beds are also warped into several gentle, minor folds with both northerly and east-westerly trends. Also, on the gentle east limb of the Tintic syncline, or west limb of the anticline, there were developed several minor folds or "crumples," some of which are overturned toward the east; some thrusting also occurred on this limb and very local "buckling" or sharp down-folding gave rise to the Tintic Standard and North Lily "pot-hole" structures.

This compressional folding was accompanied or followed closely by strong normal faulting along easterly-westerly fault zones such as the Coyote fault, the Standard-Lily fault and the South Fault and by major down-faulting along the Eureka Lilly fault near the crest of the arch. Local col-

lapse also occurred along the margins of the "pot-hole" folds, accentuating these structures.

Lovering (Lovering, 1949) has interpreted the Standard-Lily and South Faults as representing a down-folded portion of a thrust zone at or near the top of the Tintic quartzite. However, it is clear in many places in both the North Lily and Tintic Standard mines that major normal faulting has occurred along these faults, and minor thrusts which have been mapped within blocks lying between strands of the fault zones are cut by the bounding normal faults. Also in some areas at a distance from the fault zones, where the Ophir beds and the Tintic-Ophir contact are exposed in underground workings, there is no evidence of thrusting at this stratigraphic horizon. It seems more likely therefore, that the Standard-Lily and South faults, like other east-west normal faults in this area, represent the effect of expansion of the area in a northerly-southerly direction due to the west-east compression.

Following this period of major diastrophism came a long period of erosion, developing an irregular topography of rather sharp relief, in part controlled by the major fault lines previously developed in the Paleozoic beds. Then, in early Tertiary time, this part of the Tintic district was blanketed by the flows of the Packard rhyolite series, apparently flowing from vents outside this immediate area.

In post-rhyolite time came the second important period of disturbance, when widespread but relatively gentle stress resulted in the formation of many steep northeast-striking fissures, accompanied by intrusion of monzonite and monzonite-porphyry and subsequent introduction of the fluids which caused widespread alteration and deposition of the ore. The fissures are often strong and continuous for long distances but the amount of displacement is universally small. They do cut and displace the earlier faults, however, with small horizontal offsets, and "rubbly" breccias are often developed within the walls of the fissures in both the Tintic quartzite and the overlying limestone beds. The earliest of the northeast fissures served to localize the monzonite-porphyry dikes; renewed fracturing along the same zones after the intrusion of the monzonite and monzonite-porphyry permitted the injection of the pebble-dike mate-

rial into the fissures which then also served as channelways for the ore-bearing solutions and as the loci for many of the ore shoots. Where the ore-forming solutions, rising along the fissures, were fed into the trough and "pot-hole" areas, they spread upward and outward through the highly faulted blocks of ground above the "pot-holes" to form the replacement ore bodies in the North Lily mine and the great cluster of ore shoots in the Tintic Standard property.

Only very minor fracturing or faulting has occurred since the time of mineralization; some small east-west fractures cut through the northeast fissures in the North Lily mine but these are also of pre-mineral age. Locally some post-ore movement has occurred along the northeast fissures and slightly slickensided ore has been found along the Eureka Lilly fault but post-mineral movement has apparently been of minor importance and of local extent.

As shown by Plate 13, all of the important ore deposits of the Tintic Standard, Eureka Lilly and North Lily mines are found within or along the margins of the down-dropped block of ground between the Standard-Lily and South faults. This block in general dips gently to the east but near the east end of the "wedge" reversals in dip occur and at the extreme east end the beds are locally downfolded into a sharp local fold which is bounded on the east by a steep north-south, west-dipping fault zone known as the East Fault. On the upper levels this fault serves to connect the Standard-Lily and South faults. In this area both the Standard-Lily and South faults are made up of several strands, with progressive down-dip displacement of the favorable beds of the Ophir limestone, giving rise to a series of structural "steps" where the middle Ophir beds may be repeatedly faulted against the Tintic quartzite without the presence of the normally intervening lower Ophir shale (Plate 15). Such fault blocks represent particularly favorable sites for replacement ore bodies where they lie along the strike of the later mineralizing fissures. In such environments the ore also often extends laterally from the fissures along the strands of the earlier faults and may be followed upward along the faults into higher fault blocks.

Ore Deposits

As noted above, the large silver-lead ore shoots of the Tintic Standard mine are clustered within and along the margins of the fault block bounded by the Standard-Lily, South and East faults. They extend upward and outward from near the bottom of the down-dropped block on the 1450 level to the 700 level of the mine. In nearly every instance these replacement ore bodies have been localizd by a combination of three geological features: (1) the presence of the easily replaceable limestone beds in the middle unit of the Ophir formation, (2) a fault contact between these beds and the Tintic quartzite, and (3) the presence of a northeast fissure or "mineralizer." In such a geological setting the ore-forming solutions could rise along the fissures through the quartzite into the fault zones and also into the favorable beds above the faults, there to spread laterally through the beds, replacing the fractured and altered calcareous rocks with ore.

In the great Central ore body of the Tintic Standard mine, at the elevation of the 1100 level, the middle Ophir limestone was replaced by ore nearly continuously from the South Fault to the Standard-Lily fault, this interval representing a strike length of nearly 600 feet along the beds, which in plan here have the shape of a gentle crescent ,concave toward the east, and which dip gently toward the east into the narrowing wedge between the faults. Down-dip these beds are intersected by the main northeast-striking Tintic Standard fissure zone from which the ore-forming solutions spread upward and laterally through the beds. Thus, in this part of the mine a great mass of limestone, up to 200 feet in thickness, was altered and mineralized up-dip between the 1400 and 1000 levels. Within this mass a large part of the limestone was sufficiently replaced to form ore, the hypogene minerals consisting of pyrite, tetrahedrite, galena, jasperoid, quartz, marcasite and barite. The ore shoots show fissure and bedding control; locally the gently dipping beds were replaced by alternating bands of high-grade silver-lead ore and low-grade siliceous silver ore. Above the 1200 level the ore is largely oxidized, consisting of an earthy mixture of altered sandy limestone, iron oxide, vuggy quartz and jasperoid, cerussite, argentojarosite and other oxidized lead and silver minerals. The altered (dolo-

mitized) limestone above the ore bodies is iron stained, leached and locally brecciated due to oxidation of disseminated pyrite and slumping into the leached and oxidized ore below. Heavy timbering was necessary in these stopes and rock temperatures were high.

Extending outward and upward from the Central ore body are the other replacement ore bodies which occur in fault blocks between strands of the Standard-Lily, South and East faults as described above (Plate 15). These ore shoots are in general similar in character to the Central ore body, but along the southeast edge of the down-dropped wedge, above the 1000 level, one lead shoot occurs as a replacement of the upper part of the lower Ophir shale, beneath a small thrust block of Tintic quartzite. To the northwest of the central area a long discontinuous pipe of lower grade lead ore extends upward through several fault blocks from the 1000 nearly to the 700 level. To the west of this pipe, not far beneath the base of the latite flows, strong manganese oxide mineralization occurs in the Ophir beds. And to the west of the Central ore body, between the 1350 and 1250 levels, where the Ophir beds have been folded and faulted downward to the west, occurs the so-called West ore body — a local replacement of 30 to 40 feet of beds in the lower part of the middle Ophir unit.

The main lead ore body of the North Lily mine is similar in its geologic environment to the Tintic Standard ore bodies but is associated with a zone of northeast-striking monzonite-porphyry dikes as well as a strong northeast fissure zone. Here also a block of middle Ophir limestone has been faulted against quartzite by the Standard-Lily fault and cut by steep fissuring which extends into the footwall of the fault. Replacement here was also aided by the fact that the limestone beds are folded into a minor south-plunging anticline above the fault. The ore shoot extended continuously up along the fault contact from the 900 to above the 600 level with an east-west length of 50 to 120 feet and a maximum thickness of over 100 feet (see Plate 14). It bottoms on the lower Ophir shale below the 900 level. A "keel" of pyritic gold ore extends down into the quartzite along the North Lily fissure below the upper part of the ore body and lead ore also spreads easterly along the Standard-Lily fault

to the End-line Dike zone. A replacement ore shoot in the Ophir was also mined along this dike in the Eureka Lilly property.

Where the favorable Ophir beds have been faulted downward by a hanging wall strand of the Standard-Lily fault, a large lead-zinc stope was also mined above the "pot-hole" area. The ore here consisted of an incomplete replacement of the beds by galena, sphalerite and pyrite. Below this stope, in the "pot-hole" itself low-grade lead-zinc-gold occurred in a mass of brecciated lower Ophir shale and monzonite.

At the south end of the North Lily mine the gold and gold-copper ore shoots occur along both the North Lily and End-line Dike fissures within the block of Tintic quartzite south of the "pot-hole" area (Plate 14). These fissures converge toward the south in this area. The high-grade native gold-enargite ore was mined chiefly along the End-line Dike and the associated fissuring. In both zones the ore occurs in part as fissure filling along strong steep fissures but also in part as cementing material around fragments of quartzite (or monzonite) which make up rubbly breccias between fissure walls. The richer parts of the ore shoots are sometimes controlled by small cross-fractures and the southerly rake of the ore body as a whole indicates some control by the bedding of the quartzite. This southerly rake also indicates a deeper conduit for the ore-forming solutions along the intersection of the northeast fissuring and the Eureka Lilly fault. The ore becomes low grade and pyritic on the lower levels.

Likewise the gold-silver-copper ores found along the Tintic Standard and Eureka Lilly fissures within the Tintic quartzite occur both as massive fissure fillings and as cementing material for breccias within the fissure zones. The ore solutions appear to have been most strongly concentrated in local zones of unusually open fissuring or unusually strong brecciation, and in the Eureka Lilly fissure ore of commercial grade is limited to a distance of a few hundred feet vertically below the intersection of the fissures with the South Fault.

MINERALOGY OF THE ORES

A striking feature of the Tintic Standard-North Lily area is the abrupt change in the character of the mineralization where the fissures pass upward from the Tintic quartzite into the overlying Ophir formation or higher limestones, indicating that the chemical (and physical) character of the country rock was a controlling factor in the deposition of pyritic gold-copper-silver ores in the quartzite and of lead-silver-zinc ores in the calcareous rocks.

In the upper levels of the North Lily mine where the steep northeast-striking fissures pass through a fault contact into the middle Ophir limestone, the percentage of pyrite (or its oxidation products) and barite, as well as the gold content of the ore, decreases greatly within a few feet of the quartzite-limestone contact and the immediately overlying limestone has been replaced by lead ore in which the primary minerals were massive galena, accompanied by very subordinate amounts of pyrite and sphalerite (see long section of North Lily fissure zone (Plate 14). Similarly, in the Tintic Standard mine below the great silver-lead ore bodies in the Ophir limestone, which originally consisted of galena, tetrahedrite, silver sulpho-salts and jasperoid, the fissure ores contain pyrite, enargite, quartz and barite, with some tetrahedrite and clay minerals. It is true that some small shoots of galena-sphalerite-pyrite ore have been mined from fissures near the top of the quartzite, as just below the North Lily "pot-hole" area (see Plate 14), and that some low-grade pyritic gold ore has been mined from fissure and pebble-dike zones in the Ophir shale or limestone, as in the Eureka Lilly area east of the North Lily shaft, but these minor exceptions do not destroy the general sharpness of the transition between the two types of mineralization.

The typical minerals of the fissure ores are pyrite (both cubic and pyritohedral) and enargite (including the variety luzonite). Barite is an ubiquitous minor constituent. Quartz is common but rarely of the well crystallized or "vein" type. It occurs chiefly as a fine-grained variety cementing the rock fragments or pebble-dike material within the fissure walls. Locally tetrahedrite accompanies the enargite and spots of clay minerals occur sporadically in some fissures. The native gold is usually invisible except in some of the high-

grade ore along the End-line Dike fissure in the North Lily mine where it may be so abundantly dispersed as "pin-point" particles throughout the luzonite that it makes up nearly one-third (by weight) of the material and imports a golden tinge or "smear" to the sample when rubbed briskly with a rough cloth. One small veinlet of an oxidized gold-telluride was found in oxidized pyritic gold ore on the North Lily 700 level. In the pyritic gold ore without enargite the gold is apparently "locked up" in the pyrite or finely disseminated in the secondary iron oxides derived from the pyrite. Also, in the small outlying fissure ore shoots of the Baltimore area at the north end of the North Lily mine, and in the outlying Coyote area, gold values are associated with a light yellow or pale reddish variety of sphalerite (and wurtzite ?).

The siliceous ores can be divided arbitrarily on the basis of mineralization into three types — (1) pyritic gold ore, with predominant pyrite, without enargite, but with some barite, quartz and minor galena and sphalerite; (2) gold-copper ores with abundant enargite (or luzonite), native gold, pyrite and quartz and occasionally minor tetrahedrite, galena and sphalerite; (3) gold-silver-copper ores (Tintic Standard and Eureka Lilly fissures) with enargite, pyrite, tetrahedrite, accompanied by quartz, barite, clay minerals and minor chalcopyrite.

As mentioned above, the very rich gold-copper ores of the End-line Dike zone in the North Lily mine consist largely of finely divided particles of native gold in the decidedly pinkish variety of enargite known as luzonite. An analysis of a picked specimen of this material showed the following composition: gold 9.25 percent (2221 oz. per ton), silver 0.72 percent (173 oz. per ton), copper 44.14 percent, sulphur 27.43 percent, arsenic 13.98 percent, antimony 3.81 percent and iron 0.63 percent.

The mineralogy of the lead, silver-lead and lead-zinc-silver ores found largely as replacement bodies in the Ophir limestone is, in general, simple. The typical lead ore, as represented by the main North Lily ore body, consisted largely of galena and its oxidation products, anglesite and cerussite, accompanied by pyrite or iron oxides and minor amounts of sphalerite or smithsonite. The original silver was appar-

ently contained in the galena, and the low silver-lead ratio, as compared with the Tintic Standard ore, is due to the absence of tetrahedrite and other silver-bearing minerals. The galena varied in texture from fine-grained to coarsely crystalline and specimens of well-banded, fine-grained galena formed by metasomatic replacement of thin-bedded limestone or shale were common. Non-metallic gangue minerals, aside from altered and unreplaced country rock, were generally lacking, although some jasperoid and calcite occurred in the ore.

The lead-zinc-sulphide ore found on the lower levels of the North Lily mine, below the high-grade lead ore shoots, consisted predominantly of galena, sphalerite and pyrite.

One small ore shoot of an unusual type was, however, found in the "pot-hole" area just below the large lead-zinc stope above the 1200 level. This ore was very rich in silver and consisted of pyrite, pearceite, tennantite and bismuthinite with rare chalcopyrite. A recalculated analysis of this material shows 16.6 percent silver (3984 oz. per ton), copper 16.2 percent, bismuth 19.95 percent, iron 12.3 percent, sulphur 28.5 percent, arsenic 5.15 percent, and antimony 1.3 percent.

The important primary minerals of the great silver-lead ore bodies of the Tintic Standard mine were galena, with associated tetrahedrite and silver minerals such as pearceite or polybasite, and pyrite. The non-metallic constituents of the ores are mainly jasperoid and altered dolomitized limestone. The large oxidized ore bodies above the 1000 level were made up of galena, anglesite, cerrussite, iron oxide, and oxidized silver minerals, including argentojarosite.

In the Tintic Standard-North Lily area some mineral relationships which can be related to the general concept of of temperature-pressure zoning are apparent, although, as noted above, the conspicuous vertical change in mineralization — from pyrite-enargite-gold ore in the quartzite to the lead-silver-zinc association in the limestone, is probably due to structural conditions and to the chemical-physical properties of the enclosing rocks.

In the North Lily mine, for example, the rich lead-silver ore body lies above the lead-zinc stopes along the same struc-

tures and there is a definite increase in the percentage of both sphalerite and pyrite on the lower levels of the mine. The relationship of the gold-enargite-pyrite ores in the fissures to the south of the "pot-hole" to the strong lead-zinc mineralization is not entirely clear, as the enargite mineralization here appears to be connected with a different conduit at depth. The two surges of mineralizing solutions were probably nearly contemporaneous, however, and some galena, sphalerite and tetrahedrite occur in the gold-copper ores.

A general zoning with relation to the igneous rocks may also be inferred from the fact that in the North Lily replacement ore bodies, which are closely associated spatially with plugs and dikes of monzonite porphyry, sphalerite is common and the silver-lead ratio in the lead ore is approximately 1:2—while in the Tintic Standard ore bodies, situated 2000 feet to the southeast of this dike zone, zinc minerals are rare and the silver-lead ratio is approximately 2:1, due to the presence of more abundant tetrahedrite and lower temperature sulfo-salts of silver.

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ORE DEPOSITS OF THE EUREKA STANDARD, APEX STANDARD, AND IRON KING MINES

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EUREKA STANDARD MINE

The Eureka Standard mine is located in the southern part of the district about one mile south of the Tintic Standard mine at Dividend.

Ore was first discovered in the Eureka Standard area by a long crosscut from the Tintic Standard mine. The ore bodies were developed by a 1400-foot shaft and six levels consisting of drifts running generally along the strike of the Eureka Standard fault with some crosscutting into the footwall quartzite.

The main structural feature of the Eureka Standard mine is the Eureka Standard trough which is a northeasterly graben, bounded on the north by the south-dipping Iron King fault and on the south by the north-dipping Eureka Standard fault. The Iron King fault has an aggregate throw of about 500 feet and the Eureka Standard fault has a displacement of about 1200 feet. On the 900 level the trough has narrowed to a width of 1000 feet.

East of the Eureka Standard shaft the trough is covered by rhyolite. South of the trough, east-dipping Tintic quartzite is overlain by Ophir shales. North of the trough, southeasterly-dipping Tintic quartzite is overlain by Ophir and Teutonic formations. Within the trough a much thicker section of sediments includes all the formations from the top of the Tintic quartzite, at approximately the 1300 level, to the upper Cambrian Bluebird dolomite.

The Eureka Standard fault, striking northeasterly and averaging 50° in dip to the northwest, is the most important single structural element in localizing the Eureka Standard mine. Most of the ore bodies are concentrated along the plane of the main break or along the subsidiary en echelon strands.

Of prime importance in the deposition of the gold ores were the vertical gash fractures and breccias which formed in the quartzite on the footwall side of the Eureka Standard fault. Most of the ore was deposited in these northeasterly trending fissures within the quartzite and to a minor extent in the hanging-wall shales. The ore shoots also occur along creases or small thrust crumples within the fault zone.

A total of 373,000 tons of ore was produced from the property with an average content of .7 oz. gold, 9.3 oz. silver, 4 percent copper, 1.5 percent lead and .4 percent zinc. This production had a gross value of $12,000,000. The primary minerals were gold tellurides, enargite, tetrahedrite, galena and sphalerite.

APEX STANDARD MINE

The Apex Standard mine is located in the Eureka Standard trough about 1400 feet northeast of the Eureka Standard shaft.

The ore deposits were discovered on the northeastern projection of the Eureka Standard fault into Apex Standard ground. Two shafts were sunk on this property. The No. 1 shaft was located on a structural ridge which lies between the Apex Standard and the Eureka Standard troughs. This shaft penetrated the Apex Standard fault and was sunk to a depth of 900 feet. On the 900 level a considerable amount of crosscutting and drifting was carried out to the south and east to test for possible ore deposition in the bottom of the Apex Standard trough, but this met with little success. The No. 2 shaft was sunk to 1100 feet to intersect the projection of Eureka Standard orebodies along the fault zone. Small ore bodies were discovered by drifting along the Eureka Standard fault and were developed on five different levels. On the 1000 level a long extension was driven to the northeast to test for possible "pothole" ore bodies in the area of convergence of the Eureka Standard and Iron King faults; only a small quantity of fissure ore was discovered.

The Apex Standard ore deposits are structurally similar to those of the Eureka Standard mine in that they are found in conjunction with the Eureka Standard fault, and

occur in fissures in the quartzite footwall. The Apex Standard ore bodies, however, were much smaller in size and lower in value since the main production was in silver and lead rather than gold.

A total of 13,728 tons of ore was produced with an average metal content of .1 oz. gold, 13.7 oz. silver, .4 percent copper and 2.7 percent lead. This production had a gross value of $300,000.

IRON KING MINE

The Iron King mine is located in the western extension of the Eureka Standard trough about 3000 feet due west of the Eureka Standard shaft. It is the only mine in the East Tintic district where ore bodies have been discovered along the northern margin (Iron King fault) of the Eureka Standard trough.

The property has been developed by two shafts. The No. 1 shaft was located where large iron-manganese deposits occur at or near the surface in the vincity of the Iron King fault. A considerable tonnage of high-grade iron and manganese ore was shipped from these deposits. The No. 1 shaft was sunk to a depth of 1530 feet and some drifting was done on the 1300 and 1500 levels. A long adit was driven underneath the iron deposits and intersected the No. 1 shaft at the 350 level. A crosscut on the 1530 level follows the Iron King fault to the east, and where it intersects the Eureka Lilly fault, ore was discovered in a strong north-south trending fissure system within shattered Tintic quartzite.

The No. 2 shaft, subsequently located near the intersection of these two great fault zones, was sunk to a depth of 1550 feet. At least eight levels were driven to explore and develop the fissure-type ore bodies to the north and south along the Eureka Lilly fault and to the west along the Iron King fault. On the 1450 level a long crosscut was driven to the south and east to connect with the Eureka Standard 1300 level, giving a good section of the Eureka Standard trough at an elevation close to the Tintic quartzite basement.

In the vicinity of the No. 2 shaft there is a great complexity of structure where the Eureka Lilly and Iron

King faults intersect. Here the Ophir formation and Tintic quartzite are relatively near the surface due to anticlinal folding. In the western end of the property, in the vicinity of the No. 1 shaft, a great thickness of limestone formations extending down from the surface forms the gently westward-dipping limb of the main Tintic syncline. A swarm of monzonite porphyry dikes cuts through the central portion of the Iron King property from south to north extending into the North Lily and close to the Tintic Standard mines. It is probable that many potential structures in this property were plugged with igneous rock prior to the transfer and deposition of ore and this may account for the small production from this mine. The iron-manganese deposits near the No. 1 shaft occur as limestone replacement bodies adjacent to the monzonite dikes.

The production of the Iron King has consisted mainly of iron, manganese, gold and silver with occasional small values in lead and copper. Most of the gold and silver production came from the fissure-type deposits in the No. 2 shaft area. A total of 14,000 tons of gold-silver ore was produced with an average content of .1 oz. gold, 1.4 oz. silver, .1 percent copper.

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HYDROTHERMAL ALTERATION IN THE EAST TINTIC MINING DISTRICT

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INTRODUCTION

Hydrothermal alteration products are those which have been formed by the interaction of hot, water-rich, late magmatic fluids with pre-existing solid rocks. Hydrothermal minerals are distinct from those of magmatic crystallization and in comparison are relatively minor in amount. The more common hydrothermal minerals include: alunite, carbonates, chlorites, clays, micas, silica, sulfates, sulfides and zeolites. Which of these minerals were formed depends on the chemical composition of both the pre-existing rock and the introduced fluids, as well as the temperature and pressure of the environment and the length of time during which the hydrothermal solutions were active.

Hydrothermal alteration may affect large areas which are without associated ore deposits, but most ore deposits show some evidence of alteration by hypogene fluids. Because of the many variables to be accounted for during alteration, a sequence or pattern worked out for one district probably will not be applicable to another unless all conditions are fundamentally similar. Due to the fact that most mining districts show some relationship between ore deposits and hydrothermal alteration, and because the area or volume of altered rock is usually small compared to the amount of fresh rock, alteration patches and zones can be used as a general guide to ore — especially for the discovery of new districts. The relationship shown by various alteration types may be used to indicate time sequences, one or more of which may be productive of ore minerals. As a district is developed and becomes better known, certain alteration minerals may be used as more definite guides to ore than others. If such a situation exists, a knowledge of the geologic and structural environment in addition to the alteration picture is a valuable tool in the hands of the exploration geologist.

HISTORICAL SUMMARY

Lindgren and Loughlin

The earliest study of hydrothermal alteration in the Tintic district was carried out by Lindgren and Loughlin during the summers of 1911, 1913 and 1914, and discussed briefly in U. S. G. S. Professional Paper 107. Loughlin suggested that there had been three periods of alteration, the first of which included only diagenetic changes and dynamic metamorphism of the sediments prior to volcanic activity. The second period was essentially contemporaneous with volcanism and consisted of contact metamorphism, alteration of the volcanics and emplacement of the ore and gangue minerals. The third period was one of weathering and alteration by downward circulating waters.

We are most concerned with the alteration of the second period, during which the volcanics were subjected to chloritic, calcitic, epidotic, silicic, pyritic and sericitic alteration. Plagioclase and ferromagnesians bore the brunt of the attack by hydrothermal solutions. Dominant alteration in the sediments was described as silicic with minor amounts of barite. Loughlin believed that alteration during the second period was due not only to fumarolic activity, but also to ore bearing solutions.

Lindgren elaborated on the silicic alteration by dividing it into two phases. The first phase consisted of replacement of limestone and dolomite by silica (primary constituent), barite, pyrite and ore sulfides. He described the boundaries of silicic alteration as being very sharp — no transition zone between unaltered sediments and jasperoid. He theorized that the carbonate rocks had been replaced by colloidal silica which later became chalcedony or granular quartz with a resulting decrease in volume. Sulfides were precipitated before solidification of the silica gel. A generalized paragenesis of phase one minerals was described as: 1) barite, 2) silica, 3) pyrite, 4) ore sulfides.

During the decrease in volume of Lindgren's phase one silica gel, vugs and cracks were formed. Because the resulting jasperoid was brittle, additional fractures were formed during subsequent movements. The minerals of phase two were deposited in these open spaces. Paragenesis of phase

two is similar to phase one: 1) barite—more abundant and more coarsely crystalline than in phase one, 2) white crystalline quartz, 3) pyrite and ore minerals, 4) dolomite, scalenohedral calcite and aragonite.

Thus Lindgren believed that there were two periods of jasperoidization, both of which were associated with ore. Subsequent exploration and prospecting has, of course, shown that much of the jasperoid which crops out at the surface in the Tintic districts is not associated with ore.

Billingsley and Smith

In 1927 Paul Billingsley and Norman Smith submitted a manuscript to the International Smelting Company. That paper, entitled *Rhyolite alteration in the East Tintic district,* laid the groundwork for all subsequent alteration studies in this district. The main problem as Billingsley saw it then, and as it remains today, was to differentiate between "the alteration caused by ore-bearing solutions and that of other origins". Field studies were made on the surface and underground where the relationship of rhyolite to ore, or to other causes of alteration were carefully determined. Billingsley's field work was supplemented by Smith's microscopic study of altered rhyolite, and their combined efforts led to the isolation of three distinct alteration types: 1) silicification, 2) alunitization, 3) chloritization. Silicification (jasperoidization) of the rhyolite was found to exist close to intrusives and to major fissure zones which extended downward through the underlying sediments. The subjacent sediments were likewise jasperoidized. Alunitic alteration occurred as an outer halo surrounding silicified rhyolite and intrusives. Chloritized rhyolite was found to overlie dolomitized limestone; both chloritization and dolomitization indicate addition of magnesium.

During the study of the Tintic Standard ore body it became apparent that ore favored dolomitized, iron stained limestone. In one stope it was possible to trace an ore body up to the contact of overlying rhyolite. At that location the rhyolite showed chloritic alteration (chlorite, sericite, leucoxene) with veinlets of calcite, quartz and pyrite. At the surface, about 700 feet above this stope, the alteration was essentially the same, but quartz and pyrite veinlets were

much less common. As a result of this occurrence, Billingsley believed that the chloritized fissure zones in surface rhyolite accompanied by quartz and pyrite veinlets were a promising indication of ore in limestone below. According to him, this situation would be enhanced by the presence of pebble dikes, which are not necessarily ore-bearing, but are an indication that fissuring persisted to depth and was accessible to igneous emanations at the particular time.

It is interesting to note that during the two years following Billingsley's alteration report, he recommended exploration that led to the discovery of the North Lily, Eureka Lilly and Eureka Standard ore bodies, which produced a total of $30,000,000 worth of ore. On the basis of alteration in rhyolite, the South Apex and Greyhound areas were explored. No ore was discovered in either of these ventures and drifting beneath the rhyolite cover in the Greyhound area disclosed the fact that quartzite rather than carbonate rock (a prerequisite for relacement ore) was present. Subsequent exploration using altered rhyolite as a guide has proven much less successful to the extent that most prospectors and many mining companies no longer consider it useful.

Lovering, et al

By far the most comprehensive study of alteration in the East Tintic district was carried out by the U. S. Geological Survey under the direction of T. S. Lovering from 1943-1955. Most of the results of that study were published in Economic Geology Monograph 1, *Rock alteration as a guide to ore — East Tintic district, Utah.* Lovering found evidence of five stages of hydrothermal alteration which he called: 1) early barren — dolomitization of limestone and chloritization of volcanics; 2) mid-barren — argillization (formation of clay minerals) affecting primarily the volcanics, but also the sediments; 3) late barren — jasperoid, barite, cubic pyrite and calcite; 4) early productive— sericite, quartz and pyrithohedral pyrite; 5) productive — ore minerals, with very little alteration.

Unfortunately for prospectors and exploration geologists, after completing twelve years of study of alteration in the East Tintic district, Lovering has concluded that there is no infallible guide to ore.

Lovering's classification: Early barren stage — The earliest hydrothermal alteration recognized by Lovering consisted of dolomitization of limestone and chloritization of the lower part of the volcanics. Lovering's findings agreed with Billingsley's earlier poposal that this alteration in both limestone and rhyolite was caused by the same fluids, since chloritized rhyolite has been found only where hydrothermal dolomite is present beneath it.

Dolomitization of limestone has caused a coarsening of grain size in some cases, but this feature is not conspicuous. The dark limestones usually become darker when dolomitized, and the light colored limestones become lighter.

Chloritic alteration of the volcanics was not commonly intense, but was sufficient to give the rock a greenish tint. Ferromagnesian minerals were most susceptible to this alteration, although chlorite veinlets are also present.

The most notable changes which took place during the early barren stage were the removal of CaO, the addition of MgO and the reduction of ferric to ferrous iron (in the volcanics). Lovering ascribes this alteration to hot dilute solutions of $MgCl_2$ with minor $CaCl_2$, and CO_2. Organic matter was the agent which caused the solutions to be reducing in nature.

The solutions which caused this earliest alteration traveled farther and followed more channelways than did any of the succeeding emanations, but Lovering believes that nine times out of ten, ore bearing solutions followed the paths of the early barren fluids.

Mid-barren stage — Intermediate in age and very common in the volcanic rocks is the alteration characterized by a general bleaching and a network of yellowish-brown joint surfaces. Lovering has applied the term argillization to describe this alteration in which both phenocrysts and groundmass have been replaced by clays and micas. The yellow-brown color along joint surfaces has been derived from the oxidation of pyrite. Argillic alteration has also affected the carbonates and intrusives, but to a lesser extent. Alunite-quartz and beidellite-sericite-hydromica-quartz alterations have also been assigned to the mid-barren stage. Each of these types represent alteration related to monzonite in-

trusives, and the monzonite itself is commonly altered, especially the plagioclase phenocrysts. Surrounding the intrusives are successive zones of mid-barren stage alteration. Closest to the monzonite is a zone of sericitized, silicified rhyolite which grades outward through a zone of alunite-quartz alteration to argillized rhyolite. Except for this local zoning, argillized volcanics show little relation to other alteration types.

Field and experimental data indicate that all constituents of the rhyolite except quartz phenocrysts were attacked by hot acid solutions, probably containing halogens in the early part and various sulfur radicals in the latter part of the mid-barren stage. Outward from the centers of hydrothermal activity, the attack became more selective, and in the fringe zone between argillized and fresh rock the solutions were quite different from contemporaneous solutions rising in the zones of intense alteration, (probably cooler, less acid, and containing more metallic ions).

Argillization of the sediments is more closely related to ore shoots than is dolomitization, since the argillizing solutions made the carbonate rock much more permeable than did dolomitization. Lovering believes that enlargement of openings by argillization was a major factor in preparing the ground for ore, however, he also states that ore has not yet been found in any argillized rocks that do not show evidence of alteration during later stages.

Late barren stage—The alteration of this stage is characterized by jasperoid, barite and pyrite in sediments and jasperoid, barite, pyrite and calcite in the volcanics. It is more closely associated with ore than are the earlier alteration types, but it is much more extensive than the ore deposits. Late barren alteration is much more common in the carbonate than in the volcanic rocks, and it cuts and replaces hydrothermal dolomite and argillized dolomite, but is cut by later alteration and ore.

Jasperoid, the most abundant product of late barren alteration, is closely related to fissures that were followed by the ore bearing solutions, and commonly forms an envelope generally outlining the channelway. Barite is considered to be much more restricted to the conduits than is the jasperoid. Pyritic alteration is the most widespread of the

late barren stage in the rhyolite. It is easily recognized, and according to Lovering, it is closely associated with channels followed by ore solutions, tending "to lie vertically above the intersection of these channels with the base of the rhyolite." (Subsequent exploration work by Bear Creek Mining Company has indicated, however, that such is not necessarily the case). Calcitic alteration (replacement of plagioclase phenocrysts by calcite) in the rhyolite is the most inconspicuous of all the alteration types. It is most intense near areas underlain by jasperoid and replacement ore and is believed to be caused by solutions which deposited silica or sulfides and acquired lime and magnesia from the carbonates below.

CaO, MgO and CO_2 were removed from the sedimentary rocks, and SiO_2, FeS_2 and $BaSO_4$ were added. It is probable that bicarbonate solutions containing free CO_2 and SiO_2 were responsible for the jasperoidization of limestone and dolomite. The abundance of pyrite in some of the carbonates and jasperoids precludes the possibility that iron was already present as oxides and then transformed to sulfides by the action of H_2S as was probably the case in much of the rhyolite overlying the jasperoid.

The association of jasperoid and ore is so common that jasperoid has been regarded as a sure indication of ore nearby. Prospectors and geologists are not quite that lucky, but if the alteration sequence is limestone $\twoheadrightarrow$ dolomite $\twoheadrightarrow$ jasperoid $\twoheadrightarrow$ pyritic baritic jasperoid, the chance of finding ore seems very good.

Early productive stage — The distinctive minerals of the early productive stage are sericite, clear quartz and pyritohedral pyrite (differentiated from cubic pyrite of the earlier stage). Pyrite and clear quartz were precipitated in open spaces, while sericite occurs as a replacement of earlier formed clay minerals.

The chief chemical changes brought about by early productive solutions are a slight loss in SiO_2 and gains in K_2O and FeS_2. Lovering states that the solutions were relatively inactive and essentially neutral, but contained appreciable amounts of K_2O.

Sericitic alteration penetrates only a few feet into the wall rocks bordering ore zones, but extends as much as sev-

eral hundred feet along a fissure beyond the ore body. The close relationship of this alteration to ore makes sericite a very valuable guide. Easily recognizable pyritohedral pyrite is also an important clue indicating proximity to ore.

Productive stage — The productive stage followed very closely on the heels of the early productive stage, and was characterized by the precipitation of pyrite, ore minerals and little else other than minor quartz and carbonates. Alteration minerals are essentially non-existent.

Supergene alteration — The weathering of rocks in this district reflects a semiarid climate, and alkaline soil solutions favor development of allophane and montmorillonite in the igneous rocks. Unaltered rhyolite weathers to light gray masses cut by seams of caliche and limonite. Weathering agencies are less selective than hydrothermal solutions were, and phenocrysts and groundmass are affected about equally. Weathered biotite commonly has a limonite halo, but the biotite of argillized rhyolite has lost its iron and produces no limonite.

The sediments are relatively resistant to weathering in the Tintic district and disintegration is largely mechanical.

Bear Creek Mining Company

Bear Creek Mining Company has concentrated its alteration studies on jasperoidization, pyritization and sanded dolomite because they are indications of late barren or early productive fluids and thus present a better opportunity of leading to ore.

The term "jasperoid" is used to denote any rock which is composed dominantly of secondary silica, either hypogene or supergene. The majority of the silica is cryptocrystalline, although crystalline quartz and amorphous opal are present in minor amounts. Most commonly the original rocks, prior to jasperoidization, were carbonates, although shales and volcanics have also been subjected to this alteration. Original rock textures and structures may be preserved, but commonly they are destroyed. Jasperoids vary widely in color, occurring in shades of gray from sub-black to sub-white, yellow, yellow-brown, red, and combinations of the above in mottled and banded patterns. Various shades of brown

are most common. Many outcrops show evidence of brecciation and more than one period of silicification.

During past geologic studies in the Tintic mining district, the close association of jasperoid and ore deposits has been noted and much discussed. Therefore, when surface mapping of the Jenny Lind Unit Lease Tract, north of Eureka, disclosed the presence of many jasperoid outcrops it was hoped that they also might be associated with ore. Subsequent diamond drilling and geochemical testing proved that such was not the case. During the 1955 field season more than 100 Jenny Lind jasperoid samples were tested geochemically for traces of lead, copper and zinc. Of these only one gave a result of over 100 parts per million of the three metals, and the results from this one sample could not be substantiated by additional testing. Compared with this, geochemical testing of jasperoids from productive areas of the Main Tintic and East Tintic districts indicate as high as several thousand parts per million and always higher than 100 parts per million for each of the three metals. A petrographic study was begun in September 1956 to determine the difference between the barren Jenny Lind jasperoids and the productive jasperoids of the Main and East Tintic districts.

Samples of jasperoid and associated rocks were collected from surface outcrops and drill core in the Jenny Lind Tract and from known ore bodies in the Main Tintic and East Tintic districts for thin section study. The petrographic study of fifty-five jasperoid thin sections has resulted in a possible method of differentiating between the barren and productive jasperoids. Point values were assigned to textural and compositional properties and these point values were totaled for each thin section. The average total for jasperoids associated with known ore bodies is a positive value, but for barren jasperoids of the Jenny Lind Tract the average is a negative value. There are enough exceptions in the correlations to prevent a definite statement regarding the relation to productivity of any given jasperoid. However, the results are encouraging enough to enable Bear Creek to be more interested in jasperoids with a high positive value than those with a strong negative value, and where other factors such as structure, lithology and additional hydrothermal altera-

tion are favorable, a jasperoid with a high positive total may be an excellent guide to ore.

Sanded dolomite — The examination of altered Middle Ophir limestone recovered from several diamond drill holes in the Trixie target area has resulted in a hypothesis by the writer regarding the formation of sanded dolomite. Sanded dolomite is a very friable rock composed of poorly cemented dolomite grains, and varying in color from gray through yellow, brown, reddish-brown and reddish-purple.

The typical succession of carbonate types (from top to bottom) cored in Trixie area holes is:

1) Dolomitized limestone — fairly hard, with rare disseminated pyrite.
2) Dolomitized limestone — fairly hard, with disseminated or veinlet pyrite quite common, occasional veinlets of gypsum and jarosite.
3) Sanded dolomite — various shades of reds, browns and yellows, with veinlets of gypsum and jarosite, and disseminated iron oxides, **no pyrite**.
4) Fault gouge and breccia — with abundant pyrite, minor base metal sulfides, sericite and barite.

Repetition of the above sequence in several drill holes has led to the following ideas regarding the genesis of that alteration type. A proposed chronological sequence of events is:

1) Dolomitization of limestone (early barren) — This process was not 100 percent complete, thus a good deal of unreplaced calcite remained "disseminated" throughout the rock. The dolomitizing solutions were slightly alkaline or neutral and were non-oxidizing.
2) Pyritization of dolomitized limestone (late barren) — Pyrite was introduced and disseminated throughout the rock under slightly alkaline or neutral reducing conditions.
3) Oxidation of pyrite (early productive) — Neutral, potash bearing, oxidizing solutions provided the trigger which set off a final chain of reactions forming sanded dolomite.

In step 3) of the above sequence pyrite was oxidized to form iron sulfate and sulfuric acid:

$$2FeS_2 + 7O_2 + 2H_2O \longrightarrow 2FeSO_4 + 2H_2SO_4$$

The weak sulfuric acid solutions preferentially attacked undolomitized calcite leaving a poorly cemented dolomite. Various forms of iron oxides and sulfates also resulted and account for the yellow, brown, red and purple colors. Gypsum was produced by the reaction of calcite and sulfuric acid:

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2$$

$$CaSO_4 + 2H_2O \longrightarrow CaSO_4.2H_2O$$

Jarosite [$KFe_3(SO_4)_2(OH)_6$] resulted from the interaction of potassic solutions and iron sulfate.

The occurrence of sanded dolomite (varying from 50-130 feet thick) beneath unsanded, pyritized, dolomitized limestone indicates that the sanding was instigated by hydrothermal solutions originating later than the pyritizing solutions. The presence of jarosite necessitates the addition of potassium, and according to Lovering's alteration scheme, the addition of potash is an indication of early productive solutions. Therefore, the discovery of sanded dolomite beneath unsanded, pyritized dolomite may be a good guide to ore.

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SUMMARY OF EXPLORATION IN THE EAST TINTIC MINING DISTRICT

By

FRANK H. HOWD

Bear Creek Mining Company

The more important East Tintic exploration projects have been summarized in a report submitted to Bear Creek Mining Company by Gilbert and Cook. Much of the original data was obtained from Max Evans, formerly geologist for the Chief Consolidated Mining Company, and Hal T. Morris, United States Geological Survey. A brief summary of the projects is repeated here in chronological order.

1907-1916 — TINTIC STANDARD MINE

Underground exploration was carried on for a period of nine years under the direction of E. J. Raddatz to find ore related to a surface outcrop of jasperoidized limestone containing trace amounts of base and precious metals. The original exploration took place beneath chloritized, pyritized volcanic rocks at a cost of $1,500,000 before ore was encountered. The mine eventually produced 2,400,000 tons of lead-silver ore having a gross value of $80,000,000.

1916-1920 — COPPER LEAF SHAFT

A 1,245-foot shaft and 4,450 feet of drifting at the 300-, 500-, 1000- and 1200-foot levels had the purpose of finding a limestone replacement ore body beneath altered volcanics at the east end of Homansville Canyon. Slight mineralization was found in Tintic quartzite, but no ore was shipped.

1922 — WATER LILY SHAFT

A 1450-foot shaft was sunk and 3500 feet of drifting was done at the 1450 level to explore the Homansville fault beneath a patch of hydrothermally altered lavas. The drifting did not encounter the fault and no ore was shipped.

1923-1926 — APEX STANDARD MINE

Two shafts were sunk and considerable drifting was done by the Chief Consolidated Mining Company to explore the Eureka Standard and Apex Standard faults at a cost of $500,000. The most important objective was to determine if the Eureka Standard orebody projected into Apex Standard ground. Fissure vein ore bodies were discovered but were silver telluride instead of the expected gold telluride type. The mine produced about $300,000 worth of ore.

1924 — CENTRAL STANDARD SHAFT

A 640-foot shaft was cut and a total of 350 feet of drifting was completed. Minor amounts of ore were discovered in fissure veins.

1927 — NORTH LILY MINE

The North Lily ore body was discovered by drifting northwest on the recommendations of Paul Billingsley from the Tintic Standard 700 level to explore ground which was believed to be similar in structure, lithology and alteration to the Tintic Standard ore body. The mine produced 375,000 tons of gold-silver-lead ore, with a gross value of $14,000,000.

1927 — EUREKA LILLY MINE

The main Eureka Lilly ore body was discovered while carrying out the above exploration between the Tintic Standard and North Lily mines. This mine produced 250,000 tons of gold-lead-silver ore with a gross value of $4,000,000.

1928 — EUREKA STANDARD MINE

A crosscut from the 900 level of the Tintic Standard mine to explore the Eureka Standard trough resulted in discovery of fissure ore high in gold content in the footwall of the Eureka Standard fault. The original target, the Eureka Standard trough, has not yet been adequately explored. The mine produced $12,000,000 worth of gold-silver-copper fissure ore.

1943-1956 — UNITED STATES GEOLOGICAL SURVEY

Since 1943 the Geological Survey has carried out surface and underground geologic mapping, detailed studies of hydrothermal alteration, and several diamond drilling programs in the East Tintic mining district, all under the principal direction of T. S. Lovering. The latter phases of this program were largely directed to the development of new exploration techniques including geophysical, geochemical and geothermal methods, in addition to the more conventional geologic techniques. Significant intercepts of weak base metal sulfide mineralization were encountered in a deep drill hole recommended by T. S. Lovering in the Oxide area. Lesser intercepts of better grade mineralization were found in several shallow and moderately deep holes located and drilled under the direction of H. T. Morris in the Trixie area. The results of the work of the United States Geological Survey in the district led to Bear Creek Mining Company's East Tintic Project.

1946 — TINTIC STANDARD GREYHOUND AREA

A zone of pyritic alteration in volcanic rocks 2500 feet southeast of the Tintic Standard mine was the target for two 1000-foot churn drill holes. The discovery of limestone chips in the cuttings from these holes led to the driving of a drift from the 900 level of the Tintic Standard mine to explore the underlying sedimentary rocks. It was found that the chips were derived from boulders in the rubble zone between the overlying lava and Tintic quartzite. The quartzite was only weakly mineralized and no ore was shipped.

1947—NEWMONT LEASE OF APEX STANDARD MINE

Newmont Mining Company reopened the Apex Standard No. 1 and No. 2 shafts, rehabilitated drifts, crosscut to the east and south on the 1000 level, churn drilled from the surface and diamond drilled underground, searching for ore along several faults and in the sediments under altered volcanic rocks in the Oxide and South Apex (Karren) altered areas. Some fissure vein ore was found but none was shipped.

Following the termination of Newmont's lease the United States Geological Survey deepened a churn drill hole in the Oxide area by diamond drilling. This extension cut weak base metal sulfide mineralization, and recovered fossils which proved the existence of Mississippian rather than Cambrian sediments beneath the volcanics. This latter discovery led to the postulation of a north-south striking fault of large displacement west of the Oxide area.

1950-1951 — SOUTH APEX (KARREN) AREA

The Chief Consolidated Mining Company attempted to explore the middle Ophir limestone where it is in juxtaposition with the Teutonic fault in the Apex trough. Two deep churn drill holes penetrated an argillized and pyritized volcanic cover but the middle Ophir limestone was not encountered in the underlying sedimentary roks. No ore was discovered.

1954 — LONGYEAR LEASE OF HOMANSVILLE AREA

Diamond drilling was carried out to explore the middle Ophir limestone in a fault trough related to the Homansville and Canyon faults. Results are not available.

1955 TO DATE — BEAR CREEK MINING COMPANY — EAST TINTIC PROJECT

Detailed surface mapping, diamond drilling, geochemical and geophysical testing, alteration and trace element studies, and shaft sinking and drifting in the Oxide area are being carried out to prospect for base metal sulfides and silver in sedimentary rocks associated with several faults beneath altered volcanic rocks. Through July 1, 1957 Bear Creek Mining Company has concentrated its efforts on two targets: the Oxide area, about a mile southeast of the Tintic Standard mine, and the Trixie area, about a mile and a half south of the Tintic Standard mine.

Oxide area: Five diamond drill holes have been completed (three of which did not reach sedimentary rocks). These holes were drilled to check on boundaries of pyritic alteration in volcanics, to test for a shaft site, and for structural and stratigraphic information. One of the holes

confirmed by lithology the fact that Mississippian-Devonian sediments were present beneath altered volcanics in the Oxide area. Core recovery was too poor and sediments were too highly altered in the other deep drill hole to permit identification. The thickness of volcanics was found to range from 650 to 2000 feet in the Oxide area. The Burgin shaft has been sunk for the purpose of drifting in sediments about 50 feet above the water table (1050 level, elevation about 4600 feet), and to allow diamond drilling with greater core recovery at less expense than surface drilling. As of July 1, 1957 the shaft had been sunk to 1000 feet, the first 700 feet of which were in volcanics, and the bottom 300 feet were in Mississippian-Devonian sediments.

Trixie area: Detailed surface mapping is in progress, and eight diamond drill holes have been completed for the purpose of obtaining stratigraphic and structural information, and to encounter base metal sulfides in limestone beneath altered volcanics near the projected intersections of the Eureka Standard, Apex Standard, Teutonic and Eureka Lilly faults. The drill holes have confirmed the presence of sulfide mineralization in sediments within the faulted area. The dominant sulfide is pyrite, but base metal sulfides are also present. Mapping and drilling are being continued for the purpose of gathering additional information.

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ORE DEPOSITS OF THE NORTH TINTIC MINING DISTRICT*

By

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INTRODUCTION

The North Tintic mining district embraces all of the East Tintic Mountains north of the Main Tintic and East Tintic mining districts. Its south boundary may be taken approximately at a line extending east and west through Packard Peak, and its north boundary is Fivemile Pass. Ore valued at approximately $5,000,000 at current prices has been produced from four mines in the district; the bulk of this ore occurred as limestone replacement bodies in the Scranton mine, and the rest came from smaller replacement deposits at the New Bullion, Lehi Tintic, and Tintic Prince mines. Of less apparent importance are small deposits of copper at the Hot Stuff and Silver Bell prospects, and minor amounts of ore minerals are reported by Loughlin (Lindgren and Loughlin, 1919, p. 272-276) to occur at several other prospects.

DEPOSITS IN THE SCRANTON AREA

History and production

The mines of the Scranton Lead and Zinc Co. are in Barlow Canyon about 1⅓ miles east of the canyon mouth in E½ sec. 8, T. 9 S., R. 3 W. (See fig. 12.) The property of this company consists of 25 claims, most of which were located in the period between 1886 and 1891 and patented between 1893 and 1913.* Ownership passed from various individuals to the New Tintic Mining Co. in 1892; it was transferred to the Scranton Mining and Smelting Co. in 1902, and passed to the Scranton Lead and Zinc Co. in 1953. Records of production are available since 1902, but some ore was probably shipped from surface croppings before this date. The ore

*Publication authorized by the Director, U. S. Geological Survey

*All claims data used in this report were obtained from the offices of Tooele, Juab and Utah County Recorders.

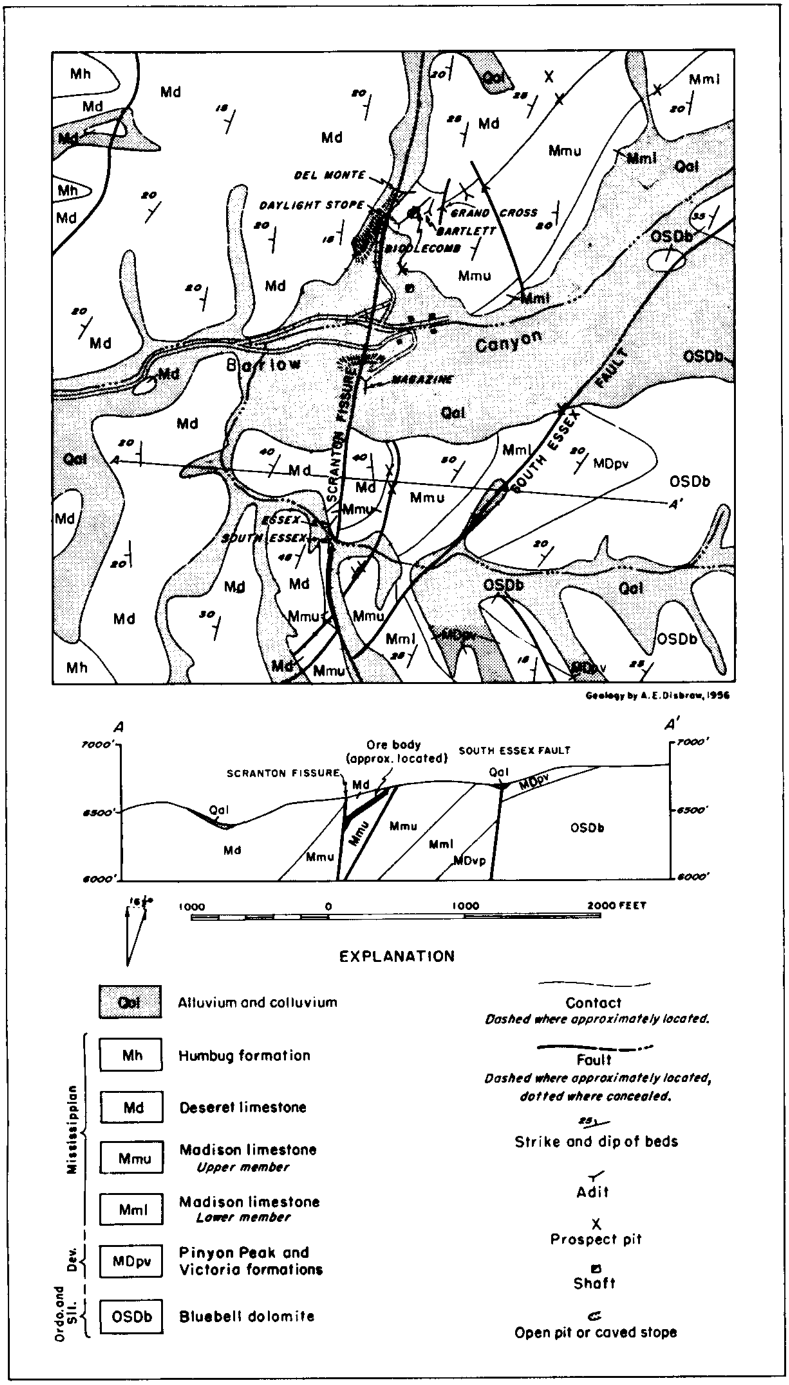

Fig. 12 Geologic map of the Scranton mine area.

bodies, most of which are adjacent to the Scranton fissure, were mined from several workings; from south to north these are: 1) the South Essex tunnel, 2) the Essex tunnel, 3) the Magazine tunnel, and 4) the Del Monte mine, which is on the north side of Barlow Canyon and consists of the Del Monte, Bartlett, Biddlecomb, and Grand Cross tunnels.

The greater part of the ore produced from the Scranton property was mined prior to 1915 by the Scranton Mining and Smelting Co. Maximum production was achieved in 1907 when 10,765 tons of ore were shipped. According to J. W. Wade (oral communication, 1955) who leased the property in 1915, virtually all ore shipped after 1915 was mined by lessees. Most of the ore shipped to the smelters was sold either as lead ore, zinc ore, or as combination lead and zinc ore (Butler, Loughlin, Heikes, and others, 1920, p. 417). Shipments of ore from the Scranton property during the period between 1902 and 1955 totaled 62,411 tons, and in aggregate average 0.69 ounces of silver per ton, 9.5 percent lead, and 16.7 percent zinc. This ore contained a total of 38,048 ounces of silver, 11,900,099 pounds of lead and 20,920,306 pounds of zinc. Gold and copper contained in the ore totaled 11.57 ounces and 3,749 pounds respectively but these metals were not recovered from most of the ore sold. The gold content ranged from 0.0034 to 0.015 ounces per ton in some lots, and the copper content of some lots ranged from 0.05 to 0.2 percent.

GEOLOGY

The ore bodies in the Scranton area occur in beds of the Madison and Deseret limestones that strike northerly, and dip westerly at moderate angles. These beds are cut by the Scranton fissure which trends north 5° to 15° east and dips steeply to the west. North of the Del Monte workings, beds are offset relatively upward about 500 feet on the east side of the fissure, but near the portal of the Essex tunnel, half a mile south of the Del Monte, the Madison-Deseret contact has been repeated, indicating that displacement on the fissure is reversed with beds on the east side of the fissure offset relatively downward about 100 feet. The Scranton fissure, where well exposed at the portal of the South Essex tunnel, is bordered by a zone of dolomite sand (porous, leached breccia of hydrothermal dolomite) that is 15 feet

wide and contains nodules and angular fragments of jasperoid.

Maps and structure sections by Loughlin (Lindgren and Loughlin, 1919, fig. 49 and pl. 39) show that most of the ore occurred as large tabular bodies in the footwall or eastern block of the Scranton fissure. These bodies of ore selectively replaced limestone beds in the upper part of the upper member of the Madison limestone, within a zone 25 to 45 feet below the basal phosphatic shale member of the Deseret limestone. A second zone from which a small amount of ore was produced occurs in the upper member of the Madison limestone about 90 feet below the phosphatic shale member. As these tabular bodies approach the fissure they diverge from the bedding and plunge down the fissure zone. Ore also extends upward and downward along steep fissures that cross the tabular bodies, and a few ore bodies are localized along minor fractures that probably join the Scranton fissure on strike or at depth.

The ore bodies in the Scranton area are nearly all oxidized and consist chiefly of cerussite, smithsonite, and hemimorphite. The character of the primary ore is indicated by a pod of partly oxidized sulfide ore in the southern stope of the Magazine tunnel. Primary minerals in this ore are described by Loughlin (Lindgren and Loughlin, 1919, p. 270) as consisting of galena, dark-brown microcrystalline sphalerite associated with dolomite, and a small amount of microcrystalline quartz and pyrite. Loughlin (Butler, Loughlin, Heikes, and others, 1920, p. 417) noted that where primary sulfides completely replaced the limestone host rock, zinc was mostly removed from lead ore during oxidation and was redeposited beneath, or down dip from, lead ore bodies. He also observed that where the sulfides impregnated the limestone but did not wholly replace it, the unreplaced limestone precipitated the zinc in place as smithsonite, and produced the lead-zinc or "combination" ore characteristic of some of the ore bodies mined in the Del Monte workings.

The geologic features that localized the ore bodies in the Scranton area include faults, fissures, and favorable stratigraphic horizons. With the exception of a small amount of ore mined from the Deseret limestone within the Scranton fissure zone itself, all of the ore bodies are localized along

fissures, or replace favorable beds of the Madison limestone within a short distance below the basal phosphatic shale member of the Deseret limestone. Except for the ore in the breccias of the Scranton fissure, all the known ore bodies occur in beds that dip moderately toward the fissure and are cut off by it. The ore-bearing solutions apparently migrated upward along the Scranton fissure and other minor fissures east of it until they encountered the barrier formed by the phosphatic shale bed, which deflected them outward and upward to the east along bedding planes. The block west of the Scranton fissure apparently was not a favorable site for ore deposition because the westerly dipping strata extend downward away from the fissure zone.

DEPOSITS AT THE NEW BULLION MINE

History and production

The New Bullion mine is in the SE¼SE¼ sec. 30, T. 9 S., R. 3 W., in the south fork of Miners Canyon about 1 mile east of the canyon mouth (see fig. 13). The principal workings are an adit, now partly caved, a winze that extends 200 feet below the adit level, and a stope that extends upward from the adit level to the surface. The property consists of four claims, which were located in 1887 and patented about 1902. Ownership of these claims was transferred from individuals to the Helen Mining Co. in 1895 and passed to the New Bullion Mining Co. in 1905. In the early 1940's W. F. Morgan (oral communication, 1955) leased the property and obtained a Reconstruction Finance Corporation loan with which he improved the road to the mine, cleaned out and retimbered some of the workings, and made a small shipment of ore.

Surface ores valued at approximately $35,000 net in lead and zinc are reported to have been mined by lessees of the property about 1897 (Butler, Loughlin, Heikes, and others, 1920, p. 416). Other production data prior to 1906 are not available. The relatively small and sporadic shipments of ore for the period between 1906 and 1955 totaled 1,528 tons and contained 2,364 ounces of silver, 261,257 pounds of lead and 388,518 pounds of zinc. In aggregate this ore averaged 8.5 percent lead and 12.7 percent zinc. The amount of silver recovered ranged from 7.2 ounces per ton to 1 ounce per ton.

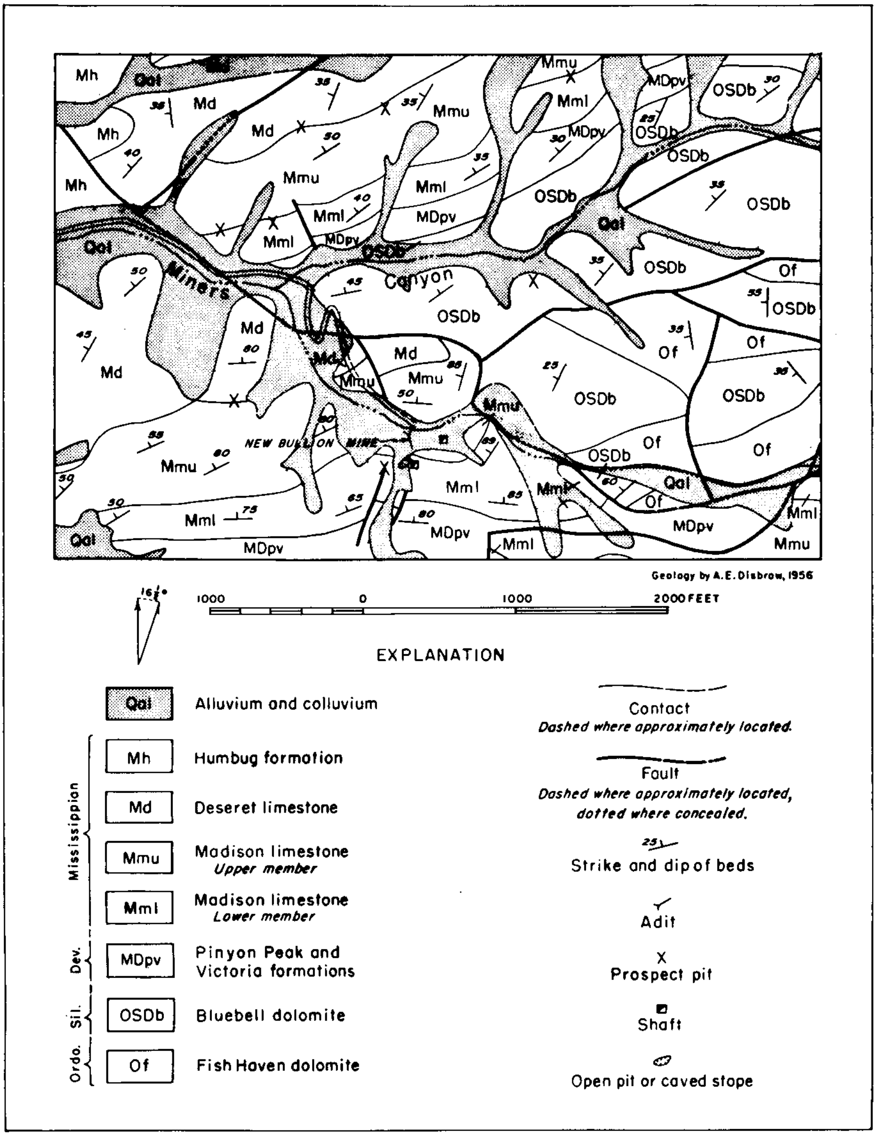

Fig. 13 Geologic map of the New Bullion mine area.

Gold was recovered from only 327 tons of ore, which yielded 5.29 ounces or 0.067 ounces per ton. The copper content of the ore was reported for 147 tons, which contained 187 pounds or about 0.06 percent.

Geology

The New Bullion area is underlain by carbonate rocks that range in age from Late Ordovician to Late Mississippian. These rocks strike easterly to northeasterly and dip steeply to moderately to the north or northwest. A short distance northeast of the mine they are cut by the New Bullion fault which trends N. 60° W. and dips about 45° to the southwest. On the ridge 600 feet north of the New Bullion adit this fault brings basal units of the Deseret limestone on the southwest side of the fault against beds in the upper part of the Bluebell dolomite on the northeast side of the fault, indicating a vertical displacement of 2,000 feet, or a horizontal displacement of 1,700 feet.

The largest body of ore in the mine cuts across bedding at a low angle near the top of the lower member of the Madison limestone. The stope that now marks the position of this ore body trends N. 50° E. and pitches northeastward at about 45°; it extends from the surface to a point a short distance below the adit level. Loughlin (Lindgren and Loughlin, 1919, p. 273) reported that small bunches of ore were mined along north-trending fissures exposed in the adit between the portal and the winze. According to W. F. Morgan (oral communication, 1955) a body of oxidized ore, which he estimated to contain 2,700 tons, occurs 45 feet below the adit level and can be reached from the winze. Morgan also reports that ore minerals fill tight fissures in the lower level drifts driven from the winze.

Loughlin (Lindgren and Loughlin, 1919, p. 273) described fragments of sulfide ore from the upper dump as containing a fine-grained mixture of galena and dark-brown sphalerite in granular white dolomite. However, most of the ore mined was almost completely oxidized, and consisted of cerussite, hemimorphite, and smithsonite in dolomite gangue. A small amount of lead-free zinc ore was mined from secondary concentrations below some of the strongly

oxidized ore bodies, which produced chiefly zinc-free lead and silver ores.

The ore deposits at the New Bullion mine apparently have been localized along fractures of small displacement in the hanging-wall block of the New Bullion fault. Ore-depositing solutions probably migrated up the fault plane, which dips toward the southwest at a moderate angle, and streamed up nearly vertical fractures in the hanging wall to the site of the known ore bodies.

DEPOSITS AT THE LEHI TINTIC MINE

History and production

The Lehi Tintic mine is owned by the Lehi Tintic Mining Co. of Salt Lake City. The property consists of 15 patented claims and fractions that are 2 miles north of Pinyon Peak in the NW¼ sec. 22, T. 9 S., R. 2 W. Little information is available concerning the early and most productive period of the mine. Loughlin (Lindgren and Loughlin, 1919, p. 276) mentioned that a good grade of oxidized silver-lead ore had been shipped from an ore body that had been mined out before he made a brief inspection of the Lehi Tintic in 1912. At that time an adit, now known as the Nichol's adit, was being driven along a fissure to prospect the ground beneath the mined-out ore body.

Somewhat later than Loughlin's visit a still longer adit was driven to a point a short distance north of the near-surface ore body. This adit is now referred to as the Main tunnel. (See fig. 14.) At a point 750 feet from the portal of this adit, according to company maps, a major winze or interior shaft has been sunk to a depth of 1,174 feet. Levels are turned from this shaft at 250 feet, 500 feet, 750 feet, and 1,100 feet, and several sublevels have been driven from raises and winzes that extend above and below the main levels. The deepest penetration shown on the company map is the 1300 level, which is reached through a series of winzes which begin on the 1100 level.

With the exception of a few tons produced in 1909, most of the ore produced to 1949 probably came from newly discovered small deposits in the deep workings, or was taken from dumps located near the old ore body. No ore has been

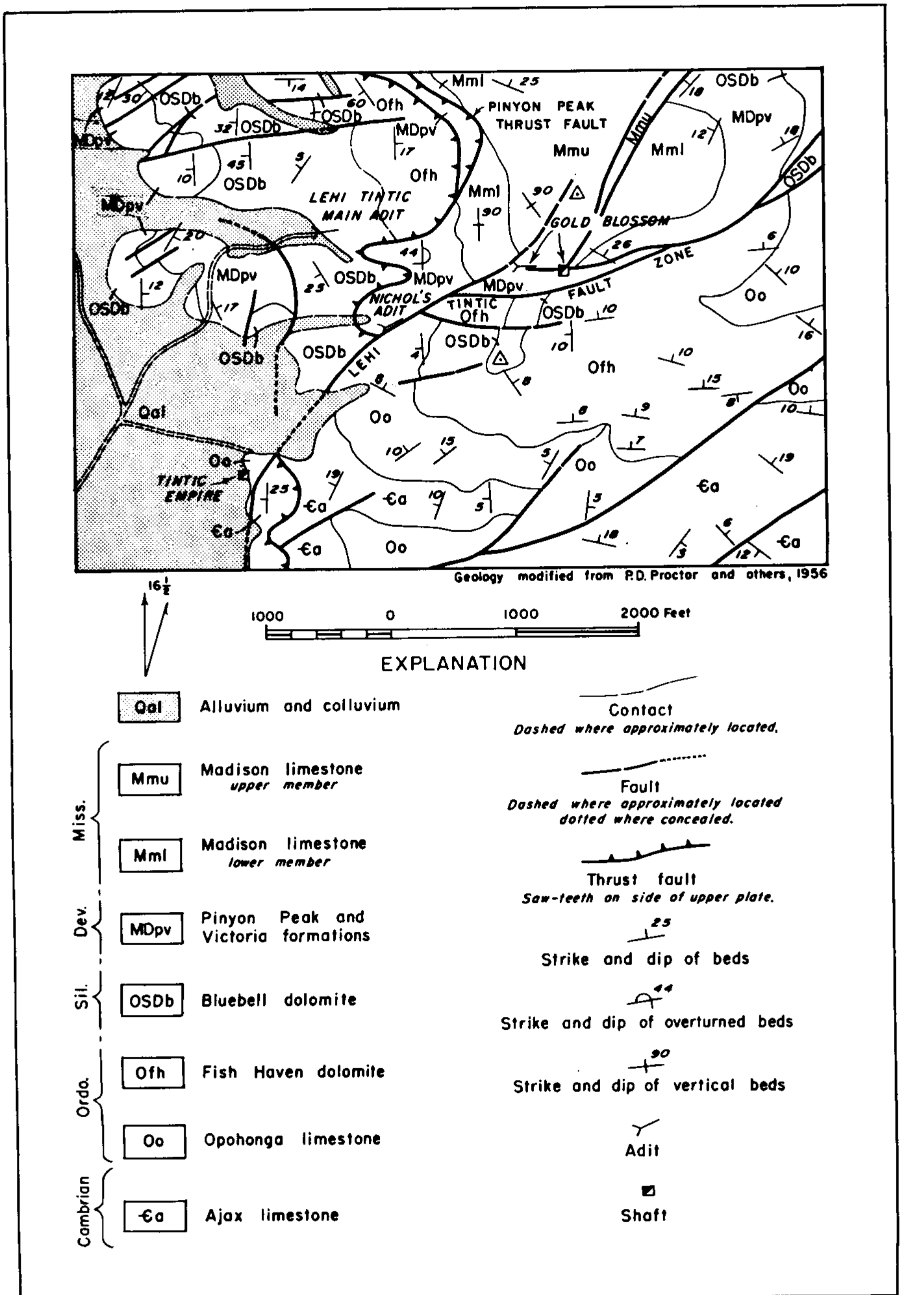

Fig. 14 Geologic map of the Lehi Tintic mine area.

produced since 1949, and that shipped between 1909 and 1949 totaled only a few hundred tons. The average lead content (about 17 percent overall) of ore shipped since 1909 is much higher than the average lead content of the ore shipped during the same interval from the New Bullion mine, but the content of silver is about the same.

Geology

The rocks exposed at the surface near the Lehi Tintic workings range in age from Late Cambrian to Early Mississippian. A short distance east of the portal of the Main adit they are cut by the Pinyon Peak thrust fault. The beds in the hanging-wall block of the thrust in general strike northerly, and dip both east and west at moderate angles. The beds in the footwall block have been dragged to vertical or overturned attitudes near the thrust plane, but a short distance east of the trace of the thrust fault they strike easterly and dip to the north and northwest at low angles. A few hundred feet southeast of the portal of the Main adit both the footwall and hanging-wall blocks of the Pinyon Peak thrust fault are cut by a northeast-trending, transverse strike-slip fault that is probably a tear fault associated with Allen's Ranch thrust fault, which crops out a mile or so east of the adit portal. The transverse strike-slip fault, which has been given the name Lehi Tintic fault on company maps, follows a sinuous branching course averaging N. 65° E.; it dips to the north at approximately 60°.

The principal ore bodies of the mine are associated with the Lehi Tintic fault. The near-surface ore bodies, which were mined prior to 1909 from the Gold Blossom tunnel and shaft, occur in fissures in the footwall block of the fault near a point where the fault plane bends to the east and several branches diverge from the principal fault plane. Other occurrences of ore have been reported from the main fault zone where it was followed by the Nichol's adit and by the 1100 level of the mine, which follows the Lehi Tintic fault for several hundred feet. Small deposits of ore have also been explored in the footwall block of the Lehi Tintic fault between the 700 and 1300 levels. The total quantity of ore produced from the lower levels, however, is not large.

The Gold Blossom ore bodies consisted chiefly of oxidized lead minerals in a gangue of jasperoid and dolomite.

The ore minerals from the 500 and 750 levels were only partly oxidized and those from the 1100 and deeper levels were essentially unaltered. The content of silver was low in all of the ores mined between 1909 and 1949, and no zinc ores have been shipped.

TINTIC PRINCE PROPERTY

History and production

The property of the Tintic Prince Mining Co. is located in Iron Canyon approximately 4½ miles northwest of Eureka in the NE¼ sec. 33, T. 9 S., R. 3 W. The property consists of 31 standard lode claims, 8 of which were patented in 1934 by the Tintic Prince Mining Co. of Salt Lake City, Utah. Two of the claims overlap an older patented claim, the Iron Cloud, which is owned by the International Smelting Co.

The property is developed by a west-trending adit 350 feet long, by an interior shaft 360 feet deep, which has been sunk from a point near the end of the adit, and by crosscuts that extend 370 feet west and approximately 300 feet east of the shaft at the 350-foot level. Numerous pits and short adits occur throughout the property.

The Tintic Prince property is still in the prospect stage of development. The principal ore occurrence was discovered in 1933 by Mr. Orlando Munding, who had established claims on ground adjacent to the Tintic Prince propertries, and held a portion of one claim in conflict with the Tintic Prince Mining Co. According to Louis Monter (personal communication, 1956), president of the Tintic Prince Mining Co., the Munding discovery yielded only a few tons of commercial grade lead ore, but it greatly stimulated surface and underground exploration of the property and the area nearby.

Geology

The principal workings of the Tintic Prince mine are on the west side of Iron Canyon about 1,500 feet northwest of the Tintic Prince fault. (See fig. 15.) The country rock includes the Tintic quartzite of Early Cambrian age, the Ophir formation, Teutonic limestone, Dagmar limestone,

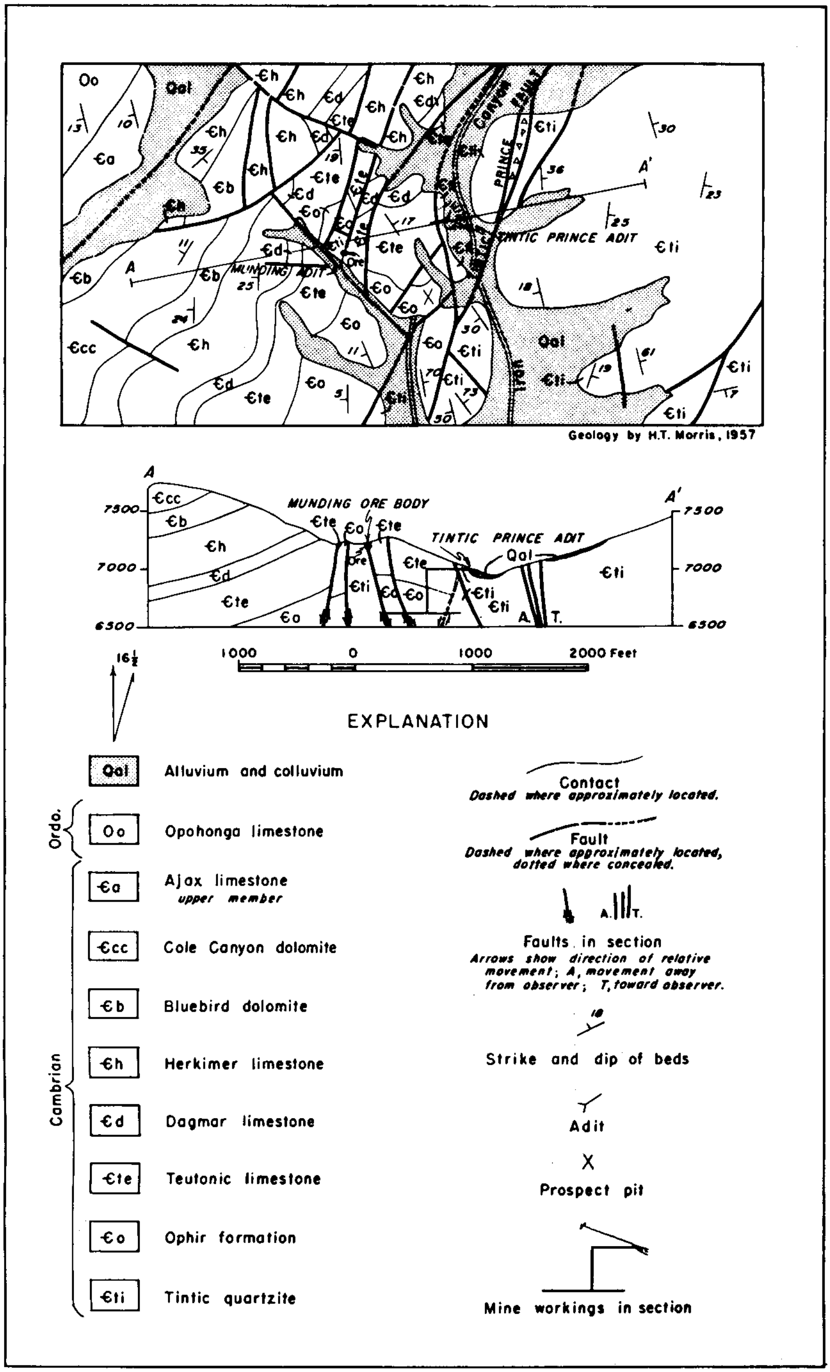

Fig. 15 Geologic map and cross section of Tintic Prince mine area,

Herkimer limestone, and Bluebird and Cole Canyon dolomites all of Middle Cambrian age, the Ajax limestone of Late Cambrian age, and the Opohonga limestone of Early Ordovician age. These strata crop out a short distance west of the crest of the North Tintic anticline and in general strike northerly and dip to the west at about 20°, although easterly dips associated chiefly with minor folds are not uncommon.

The strata exposed in the mine are cut by several steep, north-northeast trending normal and reverse faults that are more or less parallel to the Tintic Prince fault, but which are terminated by a steep, northwest-trending fault that crops out about 1,000 feet southwest of the portal of the Tintic Prince adit. The main plane of the Tintic Prince fault is exposed on the spur underlain by quartzite 500 feet northeast of the adit portal, and a major strand of the fault is cut by the adit 150 feet from the portal. Near the Tintic Prince mine the Tintic Prince fault strikes about N. 18° E. and dips about 75° to the east; northeast of the mine area the strike of the fault swings to N. 55° E. The net displacement along the Tintic Prince fault, as measured near the crest of the North Tintic anticline approximately 6,000 feet northwest of the Tintic Prince mine, is calculated to be about 7,000 feet, the block on the southeast side of the fault having moved down to the southwest at 25°.

The brecciated wallrocks of many of the faults in the Tintic Prince area have been replaced here and there by dense, dark-red to brown and black jasperoid that has obviously been brecciated and recemented several times. The jasperoidized breccias cut by the Tintic Prince adit are about 85 feet wide, but do not contain any concentrations of ore minerals. Smaller bodies of jasperoid cut by the 350 east crosscut contained small amounts of lead and gold. (Louis Monter, personal communication, 1956.)

The small Munding ore body occurs along a north-northeast trending normal fault near the point where it is cut off by the northwest-trending fault. It consisted chiefly of galena partly altered to cerussite in a slightly altered breccia composed of fragments of the Tintic quartzite and the Ophir formation. B. F. Stringham* further describes the ore as

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*Private report to Tintic Prince Mining Co. dated January 1937. Made available to the writer by Mr. Louis Monter.

Prospect	Location	REMARKS
Hot Stuff	SW¼ sec. 22, T. 9 S., R. 3 W.	Films and veinlets of copper pitch in crumpled shale; deposit is explored by pits, an adit, and 2 inclined shafts. Area is favorably regarded from standpoint of exploration possibilities.
Tintic-Humbolt	NE¼ sec 13, T. 9 S., R. 3 W.	Lead, zinc and silver reported in calcite veinlets in fault zone; explored by 2 shafts.*
Deprezin	E½ sec. 25, T. 9 S., R 3 W.	Some bismuth and traces of gold and silver reported in north-northwest trending jasperoid mass; explored by drifts from a shaft.*
Farragut	SE¼ sec. 36, T. 9 S., R. 3 W.	Lead, copper, silver and gold reported in jasperoid; deposit is explored by an adit and shaft.*
Balhinch	SW¼ sec. 29 and NW¼ sec. 32, T. 9 S., R. 3 W.	Oxidized lead and zinc ore was mined from small near-surface ore bodies in unaltered Madison limestone. Ore is similar, and probably related to New Bullion ore bodies. Quantity of ore produced not known, but believed to be small.
Silver Bell	NW¼ NE¼ sec. 5, T. 10 S., R. 3 W.	Copper carbonate minerals occur with calcite in brecciated dolomite along a northwest-trending fissure that is close to a fault of large displacement. Rocks adjacent to large fault considerably altered. Area may warrant further exploration.
Selma	E½ sec. 28, T. 9 S., R. 2 W.	Small quantities of lead and precious metals in large cavernous pipe of low-grade iron ore; explored by an adit and drifts from a shaft.*

*Data from Lindgren, Loughlin and Heikes (1919).

Figure 16. Mineral deposits in prospects in the North Tintic mining district.

consisting of pyrite, galena and quartz which replaced fault gouge. The amounts of pyrite and quartz, however, were probably small compared to ore bodies in the Main Tintic district inasmuch as no siliceous gossan overlay the Munding ore body. Minor showings of ore were also encountered in the shaft and on the 350 level as noted above, but no ore was shipped from these workings.

DEPOSITS OF ORE MINERALS IN PROSPECTS

Small deposits or occurrences of ore minerals were observed or have been reported at several prospects in the North Tintic mining district. These deposits are briefly described in Figure 16.

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ROAD LOGS

MAIN AND EAST TINTIC MINING DISTRICTS TWO-DAY FIELD CONFERENCE, OCTOBER 4th and 5th, 1957

By

DOUGLAS R. COOK and HAL T. MORRIS

FIRST DAY — General geology of the East Tintic Mountains and the geology and ore deposits of the Main Tintic mining district. Plate 17 (in pocket) shows the route of the field trip.

MILES

0.0 Assemble at the Tintic High School yard (east end of Eureka on Main Street). Turn left onto highway, then left again before railroad tracks.

0.3 Turn right on Leadville Street, continue across railroad tracks and then turn left onto dirt road.

0.7 Abandoned city well on left (small, red, brick building), continue on dirt road and bear left to the site of the Longyear 1A drill hole on top of a small hill.

1.0 **STOP 1.** (The guide is Hal Morris.) Park cars at the top of the hill. The object of this stop is to get an over-all view of Eureka and many of the mines of the Main Tintic district, and to study briefly the stratigraphy and structure (see Plate 4). Here we are looking at a cross-section of the steep western limb of the Tintic syncline. The entire stratigraphic section from the Tintic quartzite of Lower Cambrian age to the Humbug formation of Upper Mississippian age is exposed on Eureka Ridge. The town of Eureka is underlain by volcanic rocks, and Eureka Gulch has been eroded along the trace of the northeasterly-trending Leadville and Beck faults. The open stopes of the Gemini ore zone can be seen on the northern slopes of Eureka Ridge (southwest). The northern-most mine workings on the Chief ore zone are located 2700 feet vertically below the Tintic Ball Park.

The rock exposed at Stop 1 is pyritized (now oxidized to limonite) Packard "rhyolite" (quartz latite). This pyritization is probably related to the ore bodies at the northern end of the Chief ore zone.

Return to and continue across Main Street, cross over railroad tracks, bear to right and continue on paved road to the Chief No. 1 mine.

2.4 **STOP 2.** (The guide is Max Evans.) Park cars at Chief No. 1 mine. A short discussion will be given on the geology and ore controls of the Chief No. 1 mine (see Plates 7 and 8).

Continue on Chief No. 1 mine road at left side of mine dump to Highway 6-50.

2.8 Bullion Beck Shaft; bear left on highway and continue down Eureka Gulch.

3.4 **STOP 3.** (The guide is Doug. Cook.) Park cars on the right side of the highway a quarter of a mile east of the Garity silica quarry. Here we will briefly consider some further aspects of the stratigraphy and structure (see Plate 4). Most of the Cambrian section is exposed north of the highway. The Tintic quartzite exposed to the northwest, and the Dagmar limestone, due north, are easily differentiated from other formations by their distinctive colors. Note the position of the Tintic quartzite and the Dagmar limestone on Eureka ridge at the south side of Eureka Gulch; the offset from their positions north of the Gulch is due to displacement along the Beck fault, which has 1700 feet of anomalous left-lateral displacement at this point.

Continue west on highway.

3.8 Garity silica quarry on right; the Tintic quartzite is quarried here as a source of high-grade silica used in the manufacture of silica brick.

Highway forks; take left fork.

4.5 Cross railroad tracks.

5.1 Turn left at road junction to Mammoth.

5.2 **STOP 4.** (The guide is Hal Morris.) Park cars on right side of road. The objective of this stop is to ob-

serve the Tertiary and Quarternary geology of the Tintic Valley (see Plate 1, in pocket). A pediment surface cut on the Salt Lake(?) formation of Pliocene age can be seen to the west at the foot of the West Tintic Mountains. In line with the grain elevator is a prominent hill of marly limestone and bentonitic tuffs which have yielded fossils of probable Early Pliocene age. A Basin-Range normal fault is exposed at the western margin of the Boulter Mountains (northwest). The North Tintic anticline is located to the north and probably projects beneath the unconsolidated sediments of Tintic Valley. The Gilson Range can be seen to the south, with the Canyon Range behind it.

Golden Sunset mine high-up at left with the adit in Tintic quartzite.

Continue on paved road to east.

6.3 **STOP 5.** (The guide is Doug. Cook.) Park cars on the right side of the road at the west side of Mammoth. Here we will again see the sedimentary formations of the syncline, the intrusive rocks south of the syncline, and some other structural elements (see Plates 4 and 5). To the north is Eureka Ridge previously seen from Stops 1, 2 and 3. We are again looking at a cross section of the steep western limb of the Tintic syncline with rocks of Lower Cambrian to Upper Mississippian age exposed. On the south side of Mammoth Gulch are the Swansea "rhyolite" (quartz monzonite) and the Silver City monzonite stocks, both intrusive into the western limb of the Tintic syncline. The approximate trace of the Sioux - Ajax fault is due east, a short distance to the left of the letter "M" painted on the cliff-face; the discordance of the beds can be noted on either side of the fault. The circular glory hole exposed above the town of Mammoth marks the top of the famous "Mammoth ore pipe," an almost vertical cylinder of ore, 2400 feet in pitch length.

7.5 Road junction, turn left, proceed south on Highway 6-50.

8.4 Turn left at the ruins of the Tintic (Knight) smelter onto the graveled road, just before railroad tracks.

8.9 On the left are the mine shafts of the Swansea Consolidated Mining Company; this group of mines is one of the largest producers of ore from fissure veins. The veins trend north-south, and occur in pyritized quartz monzonite of the Swansea stock.

9.2 Site of Silver City, a small mining town which was prosperous in the latter part of the last century. The population of Silver City was more than 1500 at one time.

9.3 Bear right at road junction, then keep left at bend in road.

9.4 Turn right on Silver Pass road, the dirt road that goes southeast into Ruby Hollow.

10.3 Continue to east on Silver Pass road. Silver City monzonite is exposed to the left.

10.5 **STOP 6.** (The guide is Doug. Cook) Park cars at right side of road, at the mouth of Sunbeam Gulch. The objective of this stop is to see some of the intrusive and extrusive igneous rocks of the southern part of the Main district which were the host rocks for many of the fissure veins (see Plate 4). Outcrops near the mouth of the Gulch consist of Silver City monzonite. Outcrops exposed along the road east of Sunbeam gulch are of highly altered tuffs. Across Ruby Hollow to the southeast is Treasure Hill, composed of altered tuffs and probably underlain at shallow depth by monzonite. To the southwest across Ruby Hollow is the southernmost surface exposure of the Silver City monzonite.

Continue up Ruby Hollow.

11.4 Tesora mine on right.

11.7 **STOP 7.** (The guide is Hal Morris.) Park cars along Silver Pass road near its junction with the road to Diamond Gulch. From this location a great many of the mines on the fissure veins can be seen. The northeasterly trend of the fissures is apparent from the alignment of shafts, dumps and prospect pits.

A discussion will be given on the interpretation of the igneous geology of the southern part of the Main Tintic mining district (see Plates 1 and 3).

Turn right and proceed south toward Diamond Gulch.

12.3 Cross intersection of dirt roads; Joe Bowers mine to right.

12.7 **STOP 8.** (The guide is Bob Thomas.) Park cars on the mine dump of the Showers and Bowers mine. The objective of this stop is to examine the surface expression of a worked-out fissure vein. Walk to the south end of the mine dump where an open stope can be examined. Note the baritic jasperoid on projection of the fissure to the southwest. This mine has produced a small amount of silver, lead and copper ore.

Turn cars around on mine dump and proceed north to road intersection.

13.0 Turn right at road intersection, and proceed south to Diamond Gulch.

14.1 Road forks, take right fork.

Site of town of Diamond which now is almost completely obliterated. This town was one of the earliest in the Tintic mining district, once boasting a population of 900 persons and five saloons. It was deserted after vein ore bodies had been mined to the water table; the last house was moved out of Diamond in 1923.

14.4 Road forks; take right fork.

14.6 Laclede mine to right; this mine produced from a fissure vein in altered monzonite porphyry. The road continues across highly altered tuffs, latite and monzonite.

15.3 Bear left and cross intersection of dirt roads.

16.6 Junction with Highway 6-50; turn right and proceed north to Eureka.

17.1 The southernmost surface exposure of the Silver City monzonite outcrops in hill to right.

17.5 Ruby Hollow to right; continue to Eureka.

For those interested in examining the open stopes and jasperoids of the Eureka Hill mine return to Eureka and park cars at the Chief No. 1 mine (Stop 2).

STOP 9. (The guide is Max Evans.) The open stopes of the Eureka Hill mine will be examined. A walk of a third of a mile up a moderately steep road is required for this stop. A short discussion of the Gemini ore zone will be presented (see Figure 7). The nature of the Eureka Hill replacement ores can be seen, as well as the associated silicification and dolomitization. Of interest is the selective replacement of chert in the Ajax formation by dolomite and calcite.

Great caution should be exercised by those examining the open stopes and the instructions of the guide must be followed at all times.

End of first day excursion.

SECOND DAY — The geology and ore deposits of the eastern part of the Main Tintic mining district, and the geology, ore deposits and exploration of the East Tintic mining district. Plate 17 (in pocket) shows the route of the field trip.

MILES

0.0 Assemble at the Tintic High School yard. (East end of Eureka on Main Street.) Turn right onto highway, proceed southwest through Eureka.

0.7 Gemini mine [and dump] on right.

0.9 Bullion Beck mine on right near highway; both the Gemini and Bullion Beck mines are located on the northern part of the Gemini ore zone.

2.1 Highway forks, take left fork.

3.2 Cross Mammoth road intersection, continue south.

4.1 Turn left at the site of the Tintic smelter, proceed southeast on gravel road.

5.1 Continue across intersection of roads and proceed eastward up Dragon Canyon.

6.0 Dragon mine office on left; road forks, take right fork, proceed to Dragon clay mine.

6.2 **STOP 10.** (The guide is Bob Thomas.) Park cars on road south of the Dragon clay mine. Here we will see

a large body of halloysite clay formed by intensive hydrothermal alteration of a large septum of limestone at the northern margin of the Silver City monzonite stock. The clay is utilized by the Filtrol Corporation in the production of a petroleum filter-catalyst. The Dragon fissure zone can be observed in the open cuts as areas of intense limonitic and hematitic staining.

A short discussion will be given on the geology of the Dragon clay mine (see Plates 9, 10 and 11).

Proceed up hill to the Highline road. This is the roadbed of the old railroad to the Tintic smelter.

6.8 Switch-back, road forks, take left fork.

7.4 Highline road; rock exposed in old railroad cuts is altered monzonite of the Silver City stock and altered latite(?).

8.0 Iron Blossom No. 1 mine to left up hill. Ore was mined from the Iron Blossom fissure which continues to the southwest through the Governor and Dragon mines. To the northeast this fissure is aligned with the Iron Blossom ore zone.

8.4 Tintic Central mine on right, road continues in Silver City monzonite. Note the widespread hydrothermal alteration to the east; this is part of a broad northeast zone extending from the southern part of the Main Tintic district to the East Tintic district.

8.5 Talus from outcrops of contact metamorphosed sedimentary rocks higher on hill.

8.8 Altered latite tuffs in railroad cuts.

8.9 **STOP 11A.** (The guide is Hal Morris.) Park cars along road. The objective of this stop is to obtain a panoramic view of the East Tintic mining district, Utah Valley and the Wasatch Range (see Plate 12).

From northeast to southwest the following features can be seen from this vantage point: Pinyon Peak capped with the upper member of the Madison limestone, (Mississippian), Big Hill composed of argillized quartz latite, and intruded by numerous small monzonite plugs, Iron King No. 1 shaft, Apex Stand-

ard No. 1 and No. 2 shafts, Burgin shaft, Eureka Standard mine, South Apex alteration area, Trixie alteration area, and Latite Ridge. Note the color and physiographic contrast of the altered quartz latite to the north and northwest, and the fresh latite to the east of Latite Ridge. The large basin which centers in the East Tintic district was probably formed by accelerated weathering of the hydrothermally altered rocks.

Proceed northwest a few hundred feet around bend in road.

9.0 **STOP 11B.** (The guide is Hal Morris.) A short discussion will be given on the geology of the Godiva and Iron Blossom ore zones and their relation to the axis of the Tintic syncline (see Plates 4 and 6). The Iron Blossom No. 3 shaft, directly to the west, is situated a short distance north of the Sioux - Ajax fault. This fault strikes nearly due east and dips steeply to the north; the fault is normal with the north block down. At the Sioux - Ajax fault the mineralized Iron Blossom fissure zone, traceable from the Dragon mine, joins the southern end of the horizontal ore pipe of the Iron Blossom ore zone. At the fault the mineralization changes from copper - gold to lead - silver; the physical character and strike of the ore bodies also change.

Proceed to north along Highline road.

9.6 Colorado Consolidated mine; the No. 2 shaft is collared in Humbug formation.

10.0 Beck Tunnel No. 1 shaft, the road is parallel with and just east of the axial plane of the Tintic syncline at this point; note the steep dips of the beds on the western limb of the syncline and the flat dips of the beds on the eastern limb. Road is near the contact of the Deseret and Humbug formations.

10.2 Caution, open stope directly to right of road.

10.3 Beck Tunnel No. 2 shaft.

10.4 The road is parallel with, and near, the trace of the axial plane of the Tintic syncline near the contact of the Deseret and Humbug formations. North of this

point the sediments are overlain by Packard quartz latite.

10.5 Yankee shaft.

10.6 Yankee adit.

10.9 Knightsville to right on top of hill. At one time this was a town with a population of more than 1,000 people. The large concrete foundation is that of the Knightsville school. Bear left over slight rise.

11.2 On the left are the abandoned May Day and Godiva mills.

11.4 Chief No. 2 shaft on left. One of the objectives of this shaft was to explore for the northern extension of the Godiva and Iron Blossom ore zones. The effort met with little success.

11.5 Junction with U. S. Highway 6-50; turn right and proceed northeast for one-half mile.

11.9 Road forks; take right fork, the dirt road, and proceed east toward Dividend.

12.8 Pyritized Packard quartz latite.

13.1 Argillized Packard quartz latite is exposed to left across gulch.

13.3 Argillized Packard quartz latite exposed in road cuts. Big Hill shaft is on right.

13.6 Turn left onto sheep-wagon road (this turn-off is difficult to find, but is at a sharp bend in the Dividend road).

13.7 **STOP 12.** (The guide is M. B. Kildale.) Park cars on road by road cut. A short discussion will be given of the North Lily mine (see Plates 13 and 14).

An intrusive contact of monzonite with Packard quartz latite is exposed in the road cut. Note the intense argillization of the quartz latite, and the moderate argillization of the monzonite porphyry. The intense argillization of the lavas in this area is spatially related to the numerous plugs and stocks of monzonite porphyry.

The ore bodies of the North Lily mine were located approximately 700 to 1100 feet below the surface in the Ophir formation and Tintic quartzite. No ore crops out; the only expression of the mineralization is the alteration of the overlying volcanic rocks. The ore was discovered by drifting from the Tintic Standard mine on the recommendations of Paul Billingsley.

Proceed down sheep-wagon road and turn around; return to Dividend road.

14.1 Dividend road, turn left.

14.4 North Lily mine and townsite.

14.6 Cambrian dolomites crop out on hill sides on left, quartz latite on right. Road roughly follows Eureka Lilly fault zone at this point.

14.8 Eureka Lilly shaft on left.

15.0 **STOP 13.** (The guide is M. B. Kildale.) Park cars to right at bend in Dividend road. Here we will see the surface expression (alteration of sediments and volcanics) of the Tintic Standard ore bodies (see Plates 13 and 15). The jasperoid (silicified and iron-stained limestone) exposed in the roadcut encouraged E. J. Raddatz to sink the Tintic No. 1 shaft; after many discouragements he discovered the famous Tintic Standard "pothole" ore body. The jasperoid, which was probably formed by hydrothermal solutions leaking up the "South fault," contains trace amounts of precious and base metals. As in the North Lily mine no ore was exposed at the surface, the only manifestation of the concealed ore bodies being alteration principally of the Packard quartz latite, and disseminations of minute amounts of ore minerals in the altered lavas and silicified limestones.

Proceed on road through Dividend.

15.2 Road forks, take right fork. Dividend on right, Tintic Standard No. 2 shaft area on left. Dividend was a model mining camp in the days when the Tintic Standard, North Lily and Eureka Standard mines were operating. There were more than sixty families here at one time.

15.4 Cross railroad tracks, bear left.

15.7 **STOP 14.** (The guide is Frank Howd.) Park cars on right side at bend in road. The objective of this stop is to study the alteration of the quartz latite lavas which is believed to be related to the ore bodies in the Tintic Standard mine area. The zone of pyritization (marked by limonite staining at surface) forms a broad aureole coinciding with the outer limits of the Tintic Standard structural trough. Pervasive calcitic alteration of the quartz latite can be examined on outcrops directly northeast of the pyritic alteration. Within the pyritized areas the limonite staining gives way to disseminations and veinlets of pyrite at depths of 50 to 100 feet.

The hydrothermal alteration of the East Tintic district was intensively studied by T. S. Lovering (et al) of the United States Geological Survey; for more details concerning this work Monograph 1, Economic Geology (1949) should be consulted.

Continue on road.

16.1 Edge of Tintic Standard alteration halo.

16.4 Junction, keep to right.

17.0 Road junction; turn right up hill. Fresh Packard quartz latite crops out for a short distance along this road. Prominent flow structures are exposed in some of the bold outcrops on the right side of the road.

17.5 Proceed across railroad tracks; turn left to Burgin shaft.

17.7 **STOP 15.** (The guide is Jack Bush.) Park cars by the mine buildings at the Burgin shaft. A brief discussion will be given on the exploration activities of the Bear Creek Mining Company in the Oxide alteration area.

Note the pyritic alteration on Oxide Hill; its sharp western contact with fresh quartz latite can be observed several hundred feet to the west in a long north-south bulldozer cut. At this contact an indistinct dike-like body of injection breccia may be seen. The contact and injection-breccia dike dip to the west at about 75 degrees.

Turn around and return to Dividend road.

18.3 Turn left at road junction.

19.0 Turn right at road junction and proceed toward Homansville Canyon.

19.7 Junction with U. S. 6-50; turn left. Copper Leaf shaft is on top of hill to the north.

20.0 **STOP 16.** (The guide is Doug. Cook.) Park cars to right of road. The objective of this stop is to examine the pebble dikes exposed in the road cut immediately to the west. The dikes, consisting predominantly of rounded quartzite pebbles in a fine-grained matrix are believed to have been formed by late igneous processes. The quartzite from which the pebbles were derived is about a thousand feet below the present surface in this locality. Note that many of the dikes and enclosing wall rocks are pyritized. One of the dikes at the western end of the road cut is silicified, and pyrite can be identified with a hand lens.

The mineralized pebble dikes represent one of the best guides to ore, inasmuch as many of the ore bodies in the East Tintic district have been found where the pebble dike fissures cut faulted limestone and dolomite. The pebble dike swarm exposed in the road cut occupy fissures that further to the south acted as "feeders" for the North Lily and Eureka Lilly ore bodies.

Proceed to west through Homansville Canyon.

20.3 **STOP 17.** (The guide is Hal Morris.) Park cars on right side at sharp bend in road. The objective of this stop is to examine the hydrothermal alteration of dolomite adjacent to a small monzonite plug exposed in the cut at the southwest side of the road. The Herkimer limestone immediately adjacent to the plug has been dolomitized and "sanded" (strongly leached), and the plug itself has been so intensely argillized that the original character of the rock is obscured. This sanding presumably was accomplished by primary acid solutions not directly related to ore. Sanded rock is also characteristic of the alteration envelopes around

some ore bodies, but near ore bodies much of the "sand" may have been formed through the leaching effects of acids generated during oxidation of pyrite and sulfide ore minerals. Farther from the plug, dolomitized rock grades into fresh limestone.

To the south along the road the contact of the limestone with the vitrophyre member of the Packard quartz latite may be examined. This contact is mapped by the United States Geological Survey as a steep normal contact. The steepness probably is a result of the lava filling a small pre-lava canyon.

Further south across a small gulch is chloritized Packard quartz latite; this alteration is believed to be contemporaneous with dolomitization of the limestone and to have been produced by essentially the same type of altering fluids.

Return to Eureka by continuing west on highway 3.2 miles.

End of excursion.

INDEX

LIST OF MINES SHOWING TOTAL PRODUCTION AND AVERAGE GRADE

MAIN TINTIC MINING DISTRICT

Mine	Production (tons)	Average Grade Au(oz)	Ag(oz.)	Cu(%)	Pb(%)	Zn(%)	Cu-Pb Ratio
Alaska	9,640	.6	11.3	.5	2.2	1.1	.23
Ajax							
American Star	41,850	.1	13.3	.1	1.2	N	.049
Apex							
Argenta	19	N	N	.1	N	N	
Beatrice D.	212	N	22.5	.8	.9	N	.93
Beck	50,839	.1	4.7	N	20.6	N	
Black Dragon							
Black Jack	200	N	14.1	N	.2	N	
Black Warrior							
Blue Bird							
Boss Tweed							
Boston and Tintic	15	N	36.4	.1	6.9	N	.031
Brooklyn	1,923	N	14.5	1.5	.3	N	4.89
Bullion Beck	252,671	N	12	.4	8.3	.2	.048
Butcher Boy	196	N	12.6	.1	4	N	.02
Carissa	55,527	.1	6	4.9	.1	N	57.18
Centennial Eureka	1,422,402	.4	12.6	2.4	.6	N	3.92
Chief Consolidated	3,500,000	.1	15.5	.3	6	2.3	.05
Cleveland							
Colorado Chief							
Colorado, Etc.	258,608	.1	24.7	N	11.6	N	
Columbus Tunnel							
Copper Queen	133	N	12.8	1.2	.3	N	3.97
Cornucopia	81	N	10.9	.7	N	N	
Crown Point	1,717	N	3.4	.6	8.6	N	.07
Dagmar							
Diamond Queen	6	N	7.7	1.1	39.4	N	.003
Dragon and Martha Washington	321,973	.8	3.4	N	N	N	1.17
Eagle & Bluebell	668,017	.1	11.7	.2	7.5	N	.022
Emerald							
Empire	70,877	.1	7.7	.5	1.1	N	.47
Eureka Consolidated							
Eureka Hill	116,450	.7	15	.6	5.6	N	.119
Evans							
Four Aces							
Garnet	46	N	21.5	.9	N	N	
Gemini	298,052	N	31.1	.3	10.5	.1	.028
General Logan							
Godiva	124,013	.1	8.3	N	5	.5	
Gold Chain	149,341	.3	5.3	N	.5	N	7.01
Golden Key	[illegible]	N	[illegible]		.1	N	1.53
Golden Ray	1,332	[illegible]	8	.1	.2	N	
Golden Sunset							
Uncle Sam	110,842	.1	17	N	1	.2	
Undine	2,681	N	14.8	.8	2.5	N	.332
United Tintic	12	N	14	4	N	N	
Utah	5,860	.1	11.9	.1	3.1	N	.035
Victor Group	11,955	.1	6	8.9	.2	N	37.11
Victoria	13,593	.2	9.6	1	2.6	N	.388
West Morning Glory	33	.1	5.3	6.1	N	N	
West Swansea							
Wheeler							
Yankee	103,191	.1	14.8	N	1.5	1.5	
Yankee Girl Group	649	N	6.5	N	3.8	1.3	

EAST TINTIC MINING DISTRICT

Mine	Production (tons)	Au(oz)	Ag(oz.)	Cu(%)	Pb(%)	Zn(%)	Cu-Pb Ratio
Apex Standard	13,728	.1	13.7	.4	2.7	N	.14
Baltimore	1,064	.2	.2	.1	.3	N	.22
Big Hill							
Burgin							
Copper Leaf							
East Crown Point							
East Tintic Coalition							
Eureka Bullion	18,589	.3	8.9	1.8	.2	N	10.36
Eureka Lilly	245,000	.25	5.6	.8	3.6	N	.182
Eureka Standard	373,467	.7	9.3	4	1.5	.4	.243
Hannibals	3,691	.2	4.7	1.7	.1	N	29.02
Independence							
Iron King	14,001	.1	1.4	.1	N	N	
North Lily	375,000	.4	9.5	.3	13.6	.6	
Provo	182	N	10.3	3.6	N	N	
South Standard							
Tintic Bullion	81,885	1.1	5.7	1.1	1.5	1.5	.73
Tintic Standard	2,405,231	.04	24.4	.4	11.9	N	.0004
Trump							
20th Century	1,419	N	5.2	2.1	N	N	
Zuma	2,208	.2	1.7	.2	7.8	N	.019

NORTH TINTIC MINING DISTRICT

Mine	Production (tons)	Au(oz)	Ag(oz.)	Cu(%)	Pb(%)	Zn(%)	Cu-Pb Ratio
Bluff							
Bradley							
Central Standard							
Farragut							
Homansville							
Lehi Tintic	186	N	1.3	N	17	N	
New Bullion	2,000				8.5	12.7	
North Standard							
Pinyon Queen							
Scranton	62,411	N	.69	N	9.5	16.7	
Selma Mine							
Tintic Empire							
Tintic Paymaster							
Water Lily							

N—No record.

HE EAST TINTIC MOUNTAINS

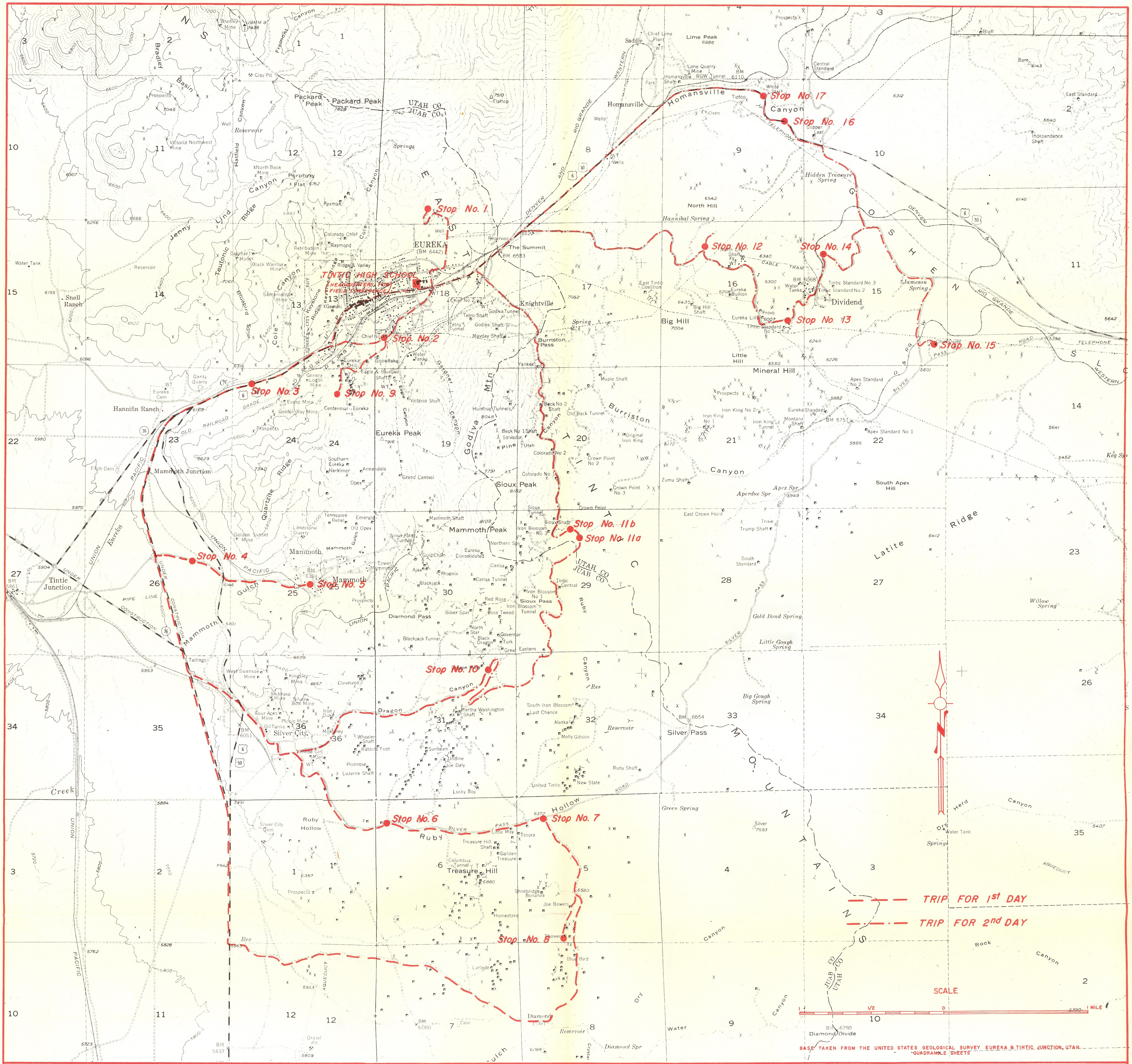

PLATE 17

MAP SHOWING THE TWO DAY TOUR OF THE MAIN AND EAST TINTIC MINING DISTRICTS

(To supplement Road Log)